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Further information concerning the preparation of technical papers is contained in "Publication Procedure for Technical Papers" (Proc. Paper 290) which can be obtained from the Society.

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Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

CONTENTS

June, 1956

Papers

(Over)

CONTENTS

DIVISION ACTIVITIES

Journal of the

SANITARY ENGINEERING DIVISION

Proceedings of the American Society of Civil Engineers

THE FEDERAL AIR POLLUTION RESEARCH PROGRAM[1]

Arthur C. Stern[2] and Robert A. Taft[3]

SYNOPSIS

The Federal air pollution research program includes research by the Public Health Service, the Weather Bureau, the Bureau of Mines, and the Bureau of Standards; research contracts negotiated by the Public Health Service with research institutes and universities; and research grants through the National Institutes of Health to individual applicants.

In setting up its air pollution research program, the Public Health Service has taken the view that the principal research resource of the nation lies in its universities, research institutes, and in the research establishments of American industry. In order to make maximum utilization of this tremendous research potential, two mechanisms are being employed: research grants and research contracts. Although both these mechanisms are aimed at tapping the same group of non-Federal researchers and research facilities, they do so by different means.

Research Grants and Research Contracts

The research grant seeks to elicit the research ideas of these researchers and to provide funds to let them undertake studies and experimental work based upon their own ideas. Since such ideas arise from all parts of the country and from persons of diverse professional skills and backgrounds, this approach has the major virtue of freeing the investigative process from the strait jacket of the limited concept of any single individual or small guiding group.

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1. Presented October 24, 1955, at the Sanitary Engineering Division Session, Annual Convention of ASCE, New York, N. Y.

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However, the very spontaneity and diversity of such ideas would tend to give a shotgun pattern to the resultant research. Certain areas of interest to individual researchers will by this mechanism be intensively investigated at the same time that other areas go untouched. To fill in the gaps, it is necessary to have a means by which some coordinating agency, in this case the Public Health Service, can contract with this same group of researchers for projects conceived by the Service as necessary for an integrated approach to the air pollution problem. This is the research contract.

Application for Research Grant

Since many of you may be potential applicants for research grants and potential recipients of research contracts, a more detailed exposition of these is in order. Specifically, there is available a lump sum earmarked for air pollution research grants. In the present fiscal year, it is a half-million dollars. Those who wish some of this money for support of their own research effort must make application on forms available for the purpose from any regional office of the Service, from the Sanitary Engineering Center in Cincinnati, from the Service headquarters in Washington, or from the Division of Research Grants, National Institutes of Health, Bethesda, Maryland. As would be expected, the applicant must describe the proposed research, its objectives, the means to be employed in trying to reach the objective, the equipment and facilities available to the researcher, the new equipment or facilities that would have to be acquired with research grant funds, the personnel proposed, their qualifications, and last, but most important of all, the qualifications of the applicant or principal researcher, who must be one and the same person.

Use of Research Grant Funds

Research grant funds may be used to pay the salary of the principal investigator and the salaries of those who work on the project under his supervision, provided all or part of the salaries of professional personnel be paid from research grant funds only to the extent that they have previously been paid from other than regular institution funds. Since there is a limit of fifteen percent overhead, it is appropriate in a research grant application that the institution sponsoring the research underwrite some of the cost of the study, at least to the extent of the remainder of the overhead costs. Actually, the applicant institution may choose to carry a larger share of the project costs, or to solicit for funds from sources other than the Public Health Service research grants program for sharing the costs of the project. Although the grant is made to one or several designated principal researchers, they must be sponsored by an institution which on the application must indicate its willingness to accept responsibility for the study and for the administration of the grant funds. Should the principal researcher change institutions, the research grant does not automatically move with him nor can the sponsoring institution automatically apply research grant funds to support someone other than the designated principal researcher. Such changes can be made only after specific Public Health Service approval.

Approval of Research Grants

Upon receipt by the Public Health Service, a research grant application is referred to a study section made up of eminent engineers, scientists, and

physicians, most of whom are non-Federal employees, who recommend approval, disapproval, or deferral of the application on its merits or ask to have it resubmitted after revision or amendment, and who finally give approved applications a priority rating. The applications from all study sections, after review by the National Advisory Health Council, and approval by the Surgeon General, are then supported to the extent of the availability of funds. For instance, if there are a million dollars worth of accepted applications and only a half-million dollars of available funds, the half-million dollars worth having the highest priority will receive support. The remaining projects that do not receive funds may subsequently receive support if and when additional money becomes available in the same or a subsequent fiscal year, provided new applications of higher priority sufficient to use up available funds are not approved in the interim.

Projects Receiving Grant Support

The first batch of projects to receive grant support from categorical air pollution funds were ten projects totaling $295,367 announced on October 3, 1955. They ranged from a minimum of $10,982 to a maximum of $ 69,209 for the current fiscal year and covered such diverse subjects as "the effect of atmospheric fluorides on man" and "a study of particulate air pollutants resulting from combustion." Several of these projects are planned for a longer period than one year. In fact, the application must indicate the anticipated length of the project and an estimate of its cost over the total time period. Where a project which is approved for more than one year's length is given a one year's grant, which is all that can be given with the funds available in any one year, there is an implicit promise of continued support for the full approved duration of the project provided sufficient research grant funds are appropriated in future years. The years of support approved may be the same or less than that requested by the applicant.

Research Contracts

Since the form of research contracts (as distinguished from research grants) is, at the time of writing, still under study, no such contracts have as yet been let. There is, however, an appropriation this year for a quarter of a million dollars for such contracts, and they will be negotiated during the next several months. Since both reasonable overhead and profit (for profit-making organizations) can be allowed in such contracts, they can be let to both profit-making research organizations and self-sustaining non-profit research institutes. It is anticipated that the size of individual contracts will be in the same range as has been indicated for research grants. There is nothing in the enabling legislation to prevent a municipality or a state from acting as sponsor for a research grant or of accepting a research contract.

Federal Research

In addition to fostering research in non-Federal establishments, the various Federal agencies themselves are undertaking a substantial air pollution research effort, a large part of which is being conducted by Federal agencies other than the Public Health Service, using funds appropriated by Congress to the Service. Specifically, $400,000 is being provided this year for research by the Weather Bureau and the Bureau of Standards of the Department of Commerce, and by the Bureau of Mines of the Department of Interior, using Public Health Service reimbursement funds.

The Weather Bureau has accepted the largest of these interagency commitments and has among other things established a field station at the Sanitary Engineering Center in Cincinnati. Weather Bureau and Public Health Service personnel are now working there side by side in a research effort to explore more fully the relationships between meteorology and air pollution, and will soon be working side by side in field studies in several parts of the United States.

The Bureau of Mines has accepted research studies on the composition of automobile exhaust, the design of incinerators, and the removal of SO_2 from stack gases; it will make available for these studies some of the best research facilities and personnel in these fields in the nation.

The Bureau of Standards' special area of interest is the development of methods and instruments for analyses of gases and vapors in the atmosphere. This is being done both at the Bureau's central research establishment in Washington and in the field. The areas chosen for field studies include Los Angeles, Louisville, and other cities having atmospheric contaminants of an extremely complex nature.

There has been some public misunderstanding to the effect that the passage of the Air Pollution Act (Public Law 159 of the 84th Congress) would result in the availability of five million dollars a year for the next five years, partly for formula grants-in-aid to states and localities. This is in error on two counts. First, although the act sets an appropriation ceiling of that amount, the actual appropriation for this fiscal year is under two million dollars. Second, the law includes no authorization for formula grant-in-aid appropriation for air pollution purposes. However, it does authorize grants for research, training, and demonstration projects.

The direct research activities of the Service, that is, those conducted by its own staff, are, although only half as large as the $ 1,150,000 extramural effort already described, nontheless large and formidable in their own right. The medical portion of the program is being handled by the Division of Special Health Services in Washington.

Medical Research by Public Health Service

The studies being undertaken by the Division of Special Health Services include statistical, epidemiological, toxicological, and physiological studies of the effect of air pollution on the health of man. These studies include:

1) Statistical studies to evaluate morbidity and mortality rates in relation to residence in areas of general or specific air pollution.

2) Epidemiological studies in regions of acute or of chronic exposure to air pollution.

3) Studies in the toxicology of specific air pollutants and development of new sensitive methods essential for determination of the health effects of pollutants in very low concentration.

4) Medical re-evaluation of standard diagnostic criteria of symptoms and diseases with respect to possible air pollution etiology. For example, correlation will be sought between residence in given areas and the occurrence of specific cell types of lung cancer as evidenced by examination of microscopic slides of lung cancer tissue.

For the furtherance of these medical studies 80 percent of this year's research contract funds have been allocated as well as a substantial part of the direct research efforts of the Service.

Non-Medical Research by Public Health Service

The non-medical portion of direct research is being handled by the Sanitary Engineering Center of the Division of Sanitary Engineering Services in Cincinnati. This latter group, which is responsible for technical assistance on air pollution to states and communities, as well as for basic air pollution research, is for research purposes divided into the following units:

Engineering Research and Development
Chemical Research and Development
Instrument and Methods Development
Meteorology

Much of the technical assistance to states and communities involves important elements of research and has resulted in the setting up of long-term cooperative Federal-state-local studies in several areas of the United States.

Engineering Research and Development

The Engineering Research group of the Air Pollution Program of the Public Health Service has as its general area of activity the determination of the nature and quantity of effluents discharged to the atmosphere, and the development of means for the reduction of the quantity or change in the nature and quantity of such effluents. In connection with this responsibility, it is developing a pilot plant and testing facility at the Center. Specific projects being undertaken this year are: An experimental study of the factors affecting the design and performance of fabric filters of the type known in industry as bag houses, dust arresters, or cloth dust collectors; an experimental study of some incinerator design factors; field studies of effluents from the cotton ginning industry and their control; and an evaluation of the various forms of micro-Ringelmann charts for measuring smoke density. In addition, this group has assigned one man full time to work with the State of California and the Los Angeles County Air Pollution Control District to assist them in their study of petroleum refinery effluents.

Chemical Research and Development

The principal research activity of this group is the National Air Sampling Network, now in its second year. This involves the collection of air samples from all parts of the United States on a routine basis and their shipment to the Center at Cincinnati for chemical analysis. This effort is, for the first time, giving a unified picture of the general pollution levels of the nation, and will prove a potent tool when correlated with the epidemiology of air pollution under study by the medical section of our program.

Instrument and Methods Development

No fields of air pollution research need more new approaches than the development of automatic instrumentation for 24-hour-a-day monitoring and surveillance of the atmosphere and the study of the exact nature of the atmospheric contaminant. One of the most exciting areas of investigation is the influence of exotic pollution on smog formation over urban areas. We feel now that we must look beyond the pollution produced by the afflicted city to the contaminant coming in with the supposedly "clean air" from the

countryside, the sea, or the lakes. There are many indications that the interaction between local and foreign contaminants may, for many communities spell smog. All these areas are now under study by this group.

Meteorology

The Weather Bureau team at the Sanitary Engineering Center has for its current projects studies in each of the following project areas: Definition and prediction of smog episodes; relationships between meteorological variables and air pollution levels; trajectories and air mass modifications; feasibility study of modeling atmospheric transport and diffusion; and development of a mobile meteorological unit and of a fixed station for the Center. In addition, by tying in the meteorological group with the several field studies under way, a new approach to air pollution sampling is being developed in which predictive meteorological data in large measure determines the kind of air sampling to be undertaken.

Air Pollution Training

Although not specifically research, no discussion of the Public Health Service program in air pollution can conclude without mention of its training program for air pollution personnel. This program was kicked off by a seminar in September, 1955, at which over 90 percent of the population was represented by persons officially designated by their respective states. Next spring a similar seminar is being held for representatives of local communities, and, in addition, three technical short courses are being offered in certain of the chemical, engineering, and meteorological phases of air pollution.

CONCLUSION

One of our eminent California colleagues has proposed that we discard the term "air pollution" and, instead, talk only about air as a resource, because air is truly our greatest natural resource. A resource connotes a limited supply and a need for conservation. Air fits these criteria, for, contrary to popular belief, it is in limited supply and in real need for conservation. In fact, if in the next century we fail to improve the protection of our atmosphere, it may well be the air resource that will limit our growth as a nation.

It is hardly necessary to point out to Civil Engineers that it has been the transport from great distances of water, fuel, electricity, materials, and food that has allowed big cities to grow. In fact, the only major resources we cannot transport to a community are its air, its weather, and its climate. In the case of these resources, we must learn to live with the local supply.

It has been said that our efforts to maintain our air resource are in the same stage of development now that our efforts to maintain our water resource were a century ago. Our goal should be to make as rapid progress in safeguarding our air during the next several decades as you have made and are still making in protecting our water resources.

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A NEW APPROACH TO TRICKLING FILTER DESIGN

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INTRODUCTION

Trickling filters have been accepted as an efficient means of secondary sewage treatment for wastes amenable to biological treatment. Among reasons reducing their usefulness may be included: 1) space requirements; 2) seasonal variation in efficiency; 3) clogging and pooling; 4) limitations on hydraulic and organic loading; 5) limitations on strength of applied sewage.

Many investigators have worked on improvements in filter design in an effort to overcome one or more of the objectionable characteristics of filters, and from these investigations the treatment field has profited. Improvements have been made in media, in circulation, in hydraulic flow rates and in methods of applying sewage to the filter.

It is the purpose of this paper to present an entirely new approach to trickling filter design, which has been investigated in the laboratory for a year. The results show that it is possible, at laboratory scale, and under controlled conditions, to treat settled domestic sewage efficiently at hydraulic rates as high as those used for rapid sand filtration of water.

The Basic Design Concept

When sewage is discharged into a shallow stream passing over and through gravel beds, it is a matter of observation that the water soon emerges with few of the characteristics of sewage. Turbulence provides repeated exposure of water surface to aeration. Flow through slime covered gravel and sand removes solids quickly. Depending, of course, on how well aerated the water is and how much filtration it receives, the water assumes clearness and is capable of accepting additional sewage. Unless the water is so cold that biological growth is inhibited, the stream bed will reach a biological balance with sufficient organism growth capable of removing substantial organic loads.

The process of natural purification categorically described above is the foundation for the system of filtration proposed here. The addition of

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controls makes possible a design with predictable results. Sewage flow is continuous, points of entry and quantities to be admitted to the filter are established. Filter space is provided with an adequate amount of oxygen to insure aerobic conditions. Enough filter depth is provided to carry conversion of organic materials to the degree of nitrification desired. Temperature of filter water is maintained in the summer range of natural streams. Since oxygen is supplied at all depths of the filter, depth limitations become those of economics, convenience, and desired degree of treatment.

This process has been named "controlled filtration." Its essentials include:

1) A trickling filter of sectional design.
2) Means for introduction and distribution of controlled quantities of sewage on to each section of the filter.
3) Means for introduction of controlled quantities of air under each section of the filter.
4) Means for maintaining influent reaching and passing through the filter at about the same temperature and preferably above 15° C and below 30° C.
5) A non-absorbing filter media sized to some degree of uniformity in order to provide media surface and ample void space (i.e. filter stone size 1 1/2 to 3 inches).
6) Means for removing effluent from sections.

It is desirable to construct the filter so that sectional effluent can be mixed with settled primary sewage or filter water as it passes through the filter.

Controlled Filtration Investigations

Laboratory Filter Unit

A diagram of the filter is shown in Figure 1. The laboratory unit was set up with metered control of settled domestic sewage taken from a Bronx, New York, sewer adjacent the Lewis Van Carpenter Sanitary Engineering Laboratory, New York University, College of Engineering. The total sewage flow was measured through a calibrated weir and pumped to the filter. Sectional feed through sections other than the top of the filter was metered through calibrated flow meters.

Air taken from the laboratory at room temperature was metered for total flow and sectional feeds were metered to adjust the proportion of air flow to the several sections.

The filter, constructed as a special structure in the laboratory, comprised six three foot sections of 12 inch ID transite pipe mounted separately on base plates. Each filter section was connected to the base plate with a transite collar drilled to provide inlet, outlet, and air connection on each collar. The collars were sealed to prevent escape of filter air. Each filter section was filled with 1 1/2 - 3 inch filter stone. The bottom section was trapped with a water seal to prevent escape of filter air.

Laboratory Studies

During the initial ripening period, hydraulic application rate to the top section was 40 million gallons per acre per day (2.2 million gallons per acre

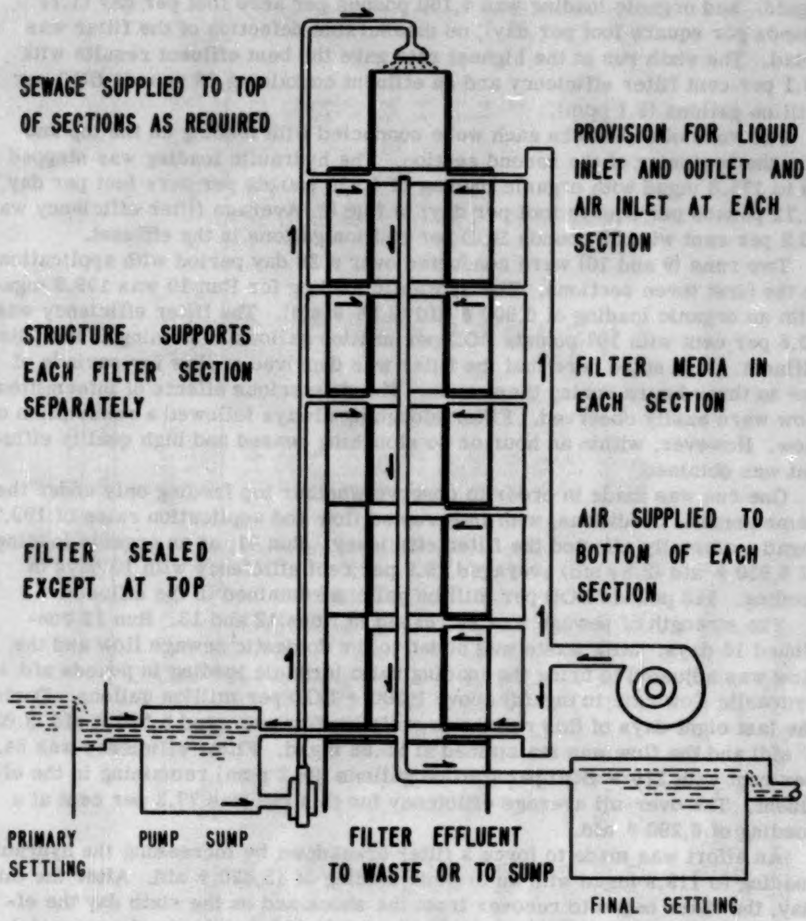

DIAGRAM OF

CONTROLLED FILTRATION

Figure 1

foot per day). A series of six runs each lasting from two weeks to one month was conducted with top feeding only in an effort to determine the maximum hydraulic loading and the limiting organic loading with top feeding. In this series during which hydraulic loading was carried up to 119.9 mgad (6.6 mgafd), and organic loading was 4,150 pounds per acre foot per day (1.71 pounds per square foot per day), no measurable defection of the filter was noted. The sixth run at the highest rate gave the best effluent results with 89.1 per cent filter efficiency and an effluent containing 68 pounds BOD per million gallons (8.1 ppm).

Two runs of two weeks each were conducted with feeding on the top and into the beginning of the second section. The hydraulic loading was stepped up to 175.8 mgad with organic loading of 4,430 pounds per acre foot per day (1.72 pounds per square foot per day) in Run 8. Average filter efficiency was 86.2 per cent with 59 pounds BOD per million gallons in the effluent.

Two runs (9 and 10) were conducted over a 28 day period with application to the first three sections. The hydraulic loading for Run 10 was 199.8 mgad with an organic loading of 6,900 # afd (2.56 # sfd). The filter efficiency was 80.8 per cent with 107 pounds BOD per million gallons remaining in the filter effluent. It is noted here that the filter was deprived of flow for periods of one to three hours during these runs. The deleterious effects of intermittent flow were easily observed. Filter sloughing always followed a resumption of flow. However, within an hour or so sloughing ceased and high quality effluent was obtained.

One run was made in order to observe whether top feeding only under the same general conditions, with interrupted flow and application rates of 199.7 mgad materially affected the filter efficiency. Run 11, at an organic loading of 6,830 # afd (2.8# sfd) averaged 75.9 per cent efficiency with 10 days of feeding. 148 pounds BOD per million gallons remained in the effluent.

The strength of sewage was increased in Runs 12 and 13. Run 12 continued 16 days. Milk waste was added to the domestic sewage flow and the flow was adjusted to bring the loading ratio (organic loading in pounds afd ÷ hydraulic flow rate in mgafd) above 1,300 # BOD per million gallons. During the last eight days of this run the organic loading averaged 8,560 # afd (3.03 # sfd) and the flow was maintained at 95.88 mgad. Filter efficiency was 84.1 per cent with 219 # BOD per million gallons (26.2 ppm) remaining in the effluent. The over-all average efficiency for this run was 77.3 per cent at a loading of 8,290 # afd.

An effort was made to force a filter breakdown by increasing the hydraulic loading to 119.9 mgad with an organic loading of 13,820 # afd. After the third day, the filter began to recover from the shock and on the sixth day the efficiency was 88.1 per cent with a loading of 11,000 # afd. On the second day, with a loading of 20,200 # afd, the efficiency was 73.5 per cent. The third day, with a loading of 15,000 # afd the efficiency dropped to 57.8 per cent, the lowest recorded in the year of study. The average for this short run was 74.1 per cent with 480 # BOD per million gallons remaining in the effluent. On the basis of comparison of filter behavior in the several runs there was no reason to believe that the recovery did not represent filter biota adjustment with the same characteristic high efficiency of removal established in all previous runs.

Table 1 summarizes the investigations by runs. Table 2 shows the maximum, minimum, and average results on BOD application and removal for each of the runs.

Table 1

Controlled Filtration

Summary of Investigations

Run	Appl. Section	Hyd. Loading MGAFD	Hyd. Loading MGAD	Organic Loading BOD ppm	Organic Loading BOD #AD (1000's lbs.)	Organic Loading BOD #AFD (1000's lbs.)	#SFD	Loading Ratio #/MG	BOD Remaining #/MG	Filter E.	Length of Run Days	Temperature °C. Max.	Temperature °C. Min.
1	1	2.2	40.[illegible]	108.5	36.15	2.01	.83	914	169	82	31	24	21
2	1	3.1	5[illegible].9	113.8	53.14	2.95	1.22	952	200	79	31	24	21
3	1	4.0	71.9	127.1	76.23	4.24	1.75	1063	173	84	14	25	21
4	1	4.9	87.8	84.3	61.86	3.44	1.42	705	85	88	19	25	22
5	1	5.8	103.9	84.6	73.18	4.07	1.68	705	88	88	14	22	18
6	1	6.7	119.9	74.7	74.49	4.15	1.71	623	68	89	14	21	18
7	1,2	8.3	143.8	78.7	94.53	5.42	2.17	656	52	92	14	21	18
8	1,2	10.4	175.8	51.1	74.92	4.43	1.72	426	59	86	14	19	18
9	1,2,3	11.1	175.8	50.3	74.05	4.65	1.70	420	61	86	7	20	18
10	1,2,3	12.4	199.8	66.8	111.51	6.90	2.56	557	107	81	21	19	18
11	1	11.1	199.8	73.7	121.97	6.83	2.80	615	148	76	10	19	17
12	1,2,3	6.1	95.9	163.7	131.11	8.29	3.01	1366	219	77	18	20	17
13	1,2,3	7.4	119.9	221.8	222.16	13.82	5.10	1851	479	74	6	19	18

Notes: Air Flow
Runs 1 - 11 1 CF per gallon sewage applied.
Run 12 2 CF " " " "
Run 13 1.7 CF " " " "

Interrupted Feeding: Runs 9 through 13.

Table 2

Controlled Filtration

Range of BOD Applied

Run	Biochemical Oxygen Demand Applied ppm Max.	Aver.	Min.	% Removal Max.	Aver.	Min.	80% or More Removal % of Observations
1	155	109	50	96	82	70	59
2	162	114	85	95	79	56	56
3	209	127	72	94	84	73	82
4	125	84	30	97	88	80	100
5	125	85	50	98	88	75	85
6	130	75	40	99	89	82	100
7	153	79	45	99	92	85	100
8	85	51	25	91	86	79	85
9	80	50	36	92	86	78	86
10	173	67	35	95	81	66	50
11	100	74	50	87	76	58	20
12	258	164	78	88	77	55	63
13	325	222	175	88	74	58	40

Observations of sectional efficiency of the filter were made periodically by extracting samples of liquid and of filter growth from each section. These profiles were of great value in assessing the behavior of the filter from top to bottom. Studies of the slime were limited to microscopic examination, but none the less, the upward and downward adjustment of groups of organisms to meet changes in loading was noted in repeated observations. Comparison of sectional observations at the end of Runs 6 and 12 (Table 3) demonstrates the organism response under top loading and three foot section loading conditions.

Dissolved oxygen measurements on liquid taken sectionally show quite conclusively the effectiveness of air admission to the sections. As might be expected, the oxygen content is low at the top of the filter where the demand is greatest and increases progressively as filter water flows downward. The effluent contained oxygen (3.2 - 5.9 ppm) at all times. Table 4 summarizes profile observations on oxygen content for the several runs.

BOD removal profiles are demonstrated in Table 5 showing sectional efficiency under the several conditions of loading. The first section removed from 21 to 70 per cent of the applied load. The significance of sectional removal characteristics will be discussed more fully later.

pH was checked on all profiles. When the applied sewage was above 7.0 there was only minor change through the filter to pH 7.2 or 7.3. When the applied waste was acid the upward change was more pronounced; that is, 0.5 or more plus. During these studies the sewage pH normally remained between 6.9 and 7.2. With milk waste added the lowest pH recorded was 6.0.

Nitrites and nitrates were checked at intervals. At 40 mgad, nitrates of 4.8 ppm were measured. At higher rates, the nitrates were never more than 1.0 ppm and were usually present at a trace only. Nitrites were found in all samples analyzed and were about 0.5 ppm during Run 6, and about 0.05 ppm during Run 10. Nitrogen determinations were too few in number to average.

Since over-all stability was of primary interest, routine tests of relative stability were made. The oxygen reserves from dissolved oxygen and nitrogen compound sources were ample in Runs 2 through 8 to maintain relative stabilities of 60 per cent or more with the majority of all observations above 80 per cent. Of 92 observations made over a span of 124 days, 45 per cent showed a relative stability of 20 or more days (99 per cent plus). It was noted that interrupted feeding and three section feeding caused a sacrifice in stability. For example, during Run 10, relative stability ranged from 21 to 75 per cent (1 to 6 days).

Settleable solids in filter effluent were measured routinely in an Imhoff cone. While there were, of course, day-to-day variations, the solids disposition was reasonably uniform without pronounced sloughing. Averages for each run are shown in Table 6. For Runs 1 through 8, the minimum observed was 0.3 ml. and the maximum was 13.6 ml. After interruption of filter flow during Runs 9 through 12, the immediate slough measured as much as 40 ml., but liquor cleared rapidly to a range between 0.2 and 12.8 ml. as measured in routine sampling.

Present Filtration Practice and Results

Tentative standards established by the Upper Mississippi and Great Lakes Board of Engineers (1) have set limits on loading for standard trickling filters of 15 pounds per 1,000 cubic feet (653.4 # afd). At that loading, the

Table 3
Controlled Filtration
Microscopic Examination
of
Filter Slime

Sample of Slime from	Run 6 Application Section 1 119.9 MGAD	Run 12 Applic. Sects. 1,2,3 Total 95.88 MGAD
Top Section 1.	Zooglea moderate Stalked ciliates moderate Rotifers numerous Flagellates few Filamentous bacteria few Branched filaments moderate Slime fairly active	Zooglea few Free swimming ciliates occasional Worms occasional Branched filaments moderate Much debris--dead sludge
Top Section 2.	Zooglea moderate Stalked ciliates moderate Free swimming ciliates moderate Flagellates moderate Rotifers moderate Filamentous bacteria moderate Branched filaments moderate Worms rare Slime very active	Zooglea moderate Stalked ciliates few (small) Free swimming ciliates very few Flagellates few Branched filaments moderate Worms rare Organisms not very active
Top Section 3.	Zooglea moderate Stalked ciliates very numerous Free swimming ciliates moderate Rotifers numerous Filamentous bacteria few Branched filaments numerous Slime very active	Zooglea very numerous Stalked ciliates few Branched filaments very numerous Slime not very active
Top Section 4.	Zooglea moderate Stalked ciliates numerous Free swimming ciliates numerous Rotifers numerous Filamentous bacteria few Branched filaments few Worms few Slime very active	Zooglea numerous Stalked ciliates numerous Free swimming ciliates very few Rotifers very few Branched filaments numerous Organisms active

Table 3 (cont'd)

Sample of Slime from	Run 6 Application Section 1 119.9 MGAD	Run 12 Applic. Sects. 1,2,3 Total 95.88 MGAD
Top Section 5.	Zooglea moderate Stalked ciliates very numerous Free swimming ciliates few Rotifers numerous Filamentous bacteria few Worms few Insects (8 legged) few Slime very active	Zooglea numerous Stalked ciliates very numerous Free swimming ciliates very few Branched filaments numerous Worms plentiful Organisms active
Top Section 6.	Zooglea moderate Stalked ciliates very numerous Free swimming ciliates moderate Rotifers numerous Branched filaments numerous Worms few Slime very active	Zooglea numerous Stalked ciliates very numerous Free swimming ciliates few Rotifers few Branched filaments few Organisms active
Effluent sludge	Zooglea moderate Stalked ciliates numerous Free swimming ciliates numerous Rotifers moderate Organisms active	Zooglea moderate Stalked ciliates moderate Free swimming ciliates moderate Rotifers moderate Branched filaments moderate Worms moderate Organisms active

Table 4

Controlled Filtration

Average Profiles Oxygen Content in PPM

Section	Number of Run											
	1	2	3	4	5	6	7	8	10	11	12	13
Influent	1.4	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Bottom 1	2.3	0.2	0.2	0.0	0.0	1.0	0.1	0.0	0.0	0.0	0.1	0.0
2	3.8	3.1	1.8	1.3	2.8	1.9	1.4	1.3	0.4	0.0	0.1	0.3
3	5.1	4.0	3.1	2.5	4.3	3.7	3.3	2.6	1.1	0.7	0.5	1.2
4	5.4	4.7	3.8	3.7	4.5	4.2	4.3	4.4	2.2	2.4	1.8	2.4
5	5.1	5.4	4.5	4.6	5.4	5.4	5.3	5.9	3.3	3.6	3.1	3.0
Effluent	5.5	5.4	5.2	4.7	5.4	5.3	5.5	5.9	3.2	4.0	3.5	3.4

Table 5

Controlled Filtration

Average Sectional Efficiency BOD Removal in %

Section	Number of Run											
	1	2	3	4	5	6	7	8	10	11	12	13
1	42.6	50.6	52.4	21.0	53.3	59.3	70.5	49.6	42.2	40.4	36.5	37.5
2	38.5	34.0	33.2	33.1	47.9	32.1	44.8	56.5	57.4	27.1	38.9	33.7
3	7.5	11.4	26.3	52.0	31.2	14.1	49.7	50.3	24.2	24.0	29.7	25.9
4	12.9	21.0	41.0	40.6	9.1	69.3	21.5	-18.9	7.7	5.1	29.3	5.2
5	21.1	5.3	0.0	29.8	37.0	-10.4	6.8	52.2	26.2	4.2	16.9	18.3
6	8.4	6.0	20.9	12.5	-18.2	37.5	29.4	7.0	1.6	16.1	14.1	8.2
1 through 6	79.5	79.7	89.1	90.8	88.3	94.9	94.1	92.2	80.3	74.8	80.4	70.6

Table 6

Controlled Filtration

Settled Solids in Filter Effluent

Run	Average Settleable Solids Ml in Imhoff Cone (1000 ml.) Max.	Aver.	Min.
2	5.3	2.7	0.5
3	5.2	1.5	0.3
4	13.6	2.3	0.3
5	5.2	2.6	0.5
6	3.8	1.7	0.3
7	4.2	1.6	0.3
8	1.6	1.1	0.4
9	4.6	2.0	1.2
10	5.2	2.1	0.2
11	12.0	3.4	1.5
12	12.8	5.3	2.6
13	4.4	3.8	2.8

curve indicates a range of 86 to 77 per cent BOD removal depending on latitude. A general limitation is placed on hydraulic loading so that the rate is less than 4 mgad.

When recirculation or "high rate" filtration is practiced, the general limits are 30 # per 1,000 cubic feet (1,310 # afd) and 10 to 30 mgad. Up to 4,800 # afd of applied load including recirculation will be considered when BOD of 30 ppm or more is acceptable. Standard filter depths are suggested at 5 to 7 feet above the under drains.

The National Research Council conducted an exhaustive study of trickling filter performance and reported (2) a mathematical formula for calculating efficiency of filters with secondary and intermediate clarifiers.

Velz presented a theory applicable to biologic beds (3) which states "the rate of extraction of organic material per interval of depth of a biological bed is proportional to the remaining concentration of organic matter measured in terms of its removability." Velz further suggests that one pound BOD per square foot per day at a temperature near 30° C is about the limit of loading and states "the removable fraction L can be expected to decrease as the rate of application of mgad increases."

Rankin(4) in reviewing the work cited above and applying the methods of evaluation to additional filter data concludes that "dosing rate, loading of the filter, or depth of filter have no significant effect within the range of values covered by the data," but indicates that the ratio of recirculation is important.

Imhoff(5) has indicated that trickling filters can be highly loaded if dosed continually at loadings of 0.8 meters per hour (2.62 feet per hour, 20.5 mgad). An example of an experimental plant at Markleeberg, near Leipzig, is cited in which surface loadings of 4.8 meters per hour (15.7 feet per hour, 122.8 mgad) were achieved with BOD removal of 90 per cent. Depth of filter was considered an essential. The experimental plant was 8 meters deep and the hydraulic loading was approximately four times that of the usual high rate filter.

One of the largest scale operations with an enclosed aerated filter is the installation at Dalmarnock Sewage Works in England. Publications by Hunter and Cockburn (6) and Cameron and Jamieson (7) described experience with this filter in detail. The filter is referred to as an Enclosed Activated Biological Filter. It is 52 feet diameter with 18 feet of filtering material. It was designed to handle hydraulically 388 gallons per cubic yard per day (14.37 gallons Imperial per cubic foot or .751 mgafd).

During the years 1938 to 1942, chemically precipitated sewage (about 137 ppm BOD) was applied with removal ranging from 57 to 94 per cent for the various test conditions. Maximum air supply was 5,000 cfm introduced at the top of the filter. A comparison made with open filters indicated that the enclosed filter treated twice the volume of waste with an equal degree of purification.

The later studies of Cameron and Jamieson offered additional data on organic loading. Application ranged from 163 to 1,266 # afd, with removal above 80 per cent. Hydraulic dosage was brought to 12.12 million gallons Imperial per acre per day (14.54 mgad) during the last year of records presented. The surface loading at that time was between 0.287 and 0.531 # sfd.

These two studies brought out a number of important characteristics. At those flow rates, ponding was a problem. The bottom half of the bed did not

perform much biochemical work but did act as a refuge for scavengers. Filter water temperature retention was an important influence. Recirculation was beneficial in controlling filter growth.

Arnold[8] studying the effects of low temperature of trickling filters compared open and enclosed filter performance at February and June temperatures. Winter temperatures of housed and open filter effluent were 43.6° and 36.6° F. Corresponding summer temperatures were 66.5° and 67.1° F. It was observed that open filter efficiency was but little lower even under severe winter conditions and was higher during warm weather.

Gerber[9] points out that several variables of design and loading must be considered in combination and suggests the use of a dimensionless product as a basis for design by plotting the ratio of BOD of effluent to applied BOD $\left(\frac{BOD_D}{BOD}\right)$ against the filter aereal loading (H in feet per day) divided by the quantity [depth times K_1 expressed in units of 1/day] $\left(\frac{H}{DK_1}\right)$, a linear curve having a slope of 0.051 was derived for Baltimore filter influent of 120-140 ppm BOD. The value, $K_1 = 0.2$ at 20° C, was assumed for these computations. A variation in K_1 will change the intercept but does not affect the slope of the curve.

Significant Characteristics of Controlled Filtration

The controlled filter is capable of handling extremely high hydraulic and organic loads by comparison with present practice. Assuming that the National Research Council efficiency curve applies at organic loading rates used, an efficiency of 65 per cent could be expected at a loading of 4,000#afd. It will be observed from Table 1 that in Runs 5 and 6, 88 per cent and 89 per cent efficiencies were obtained at about 4,000 # afd loading. Figure 2 demonstrates filter efficiency for the several conditions of loading together with the National Research Council curve. Regardless of loading, the filter efficiency is well above that shown by the National Research Council curve.

Table 7 shows an analysis of first section loading. Performance of the first section is comparable to that expected according to the National Research Council formula.[2] Average efficiency for the first six runs was 46.5 per cent at an averaged loading of 18,350 # afd on a three foot depth. The average for application to the first section for 13 runs was 46.3 per cent removal with an average loading of 23,490 # afd. The National Research Council efficiency at 18,000 # afd would be 46.7 per cent and at 24,000 # afd would be 43.2 per cent. (Figure 3)

An attempt was made to reconcile performance of the sectional filter with the theory advanced by Velz.[3] There were a number of considerations which made this practically impossible. As Table 5 illustrates, sectional extraction was not at a logarithmic rate. Only by choosing straight lines which connected BOD removal values at the beginning and at some depth could an approximate rate of removal line be selected.

The theoretical L or total removable BOD varied for the several runs suggesting strongly that the ultimate amount of removal BOD may be 95 per cent or more. Removals were calculated for each of Runs 1 through 6 on the assumption that the effluent BOD was entirely nonremovable BOD. L, therefore, varied from 0.794 to 0.949. Three reasonably straight lines could then

CONTROLLED FILTRATION

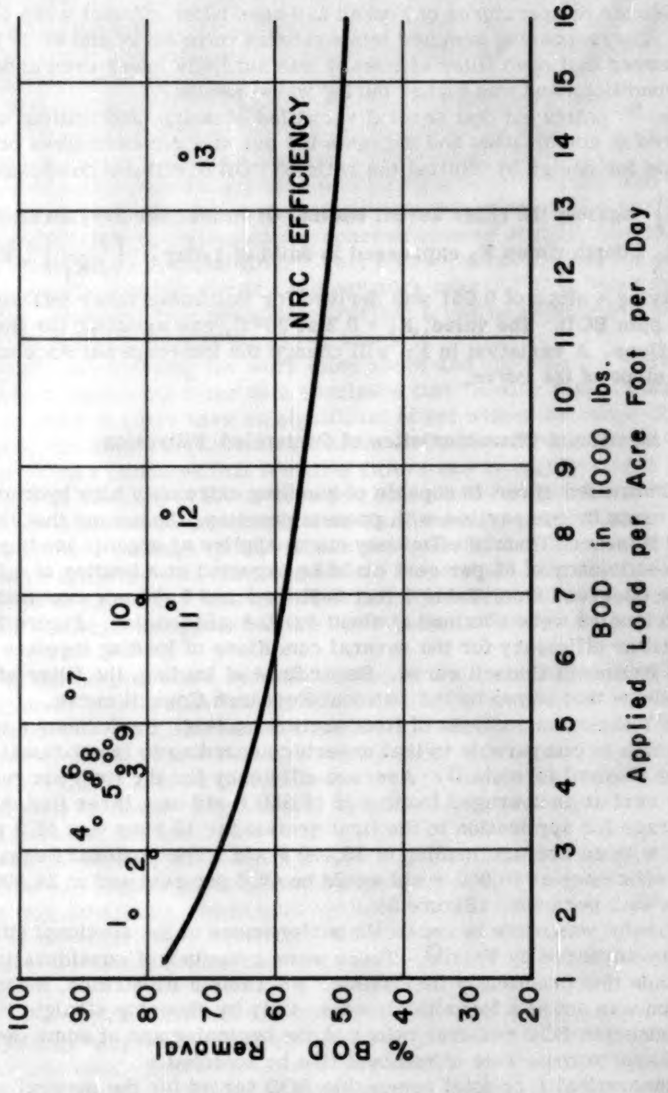

Figure 2

Table 7

Controlled Filtration

Analysis of First Section Loading

	RUN											
	1	2	3	4	5	6	7	8	10	11	12	13
BOD Applied to 3 Foot Section												
1000 #AD	31.68	50.13	76.83	55.62	56.97	59.04	81.33	51.03	62.04	127.89	67.38	125.76
1000 #AFD	10.56	16.71	25.61	18.54	18.99	19.68	27.11	17.01	20.68	42.63	22.46	41.92
ppm	95.0	107.4	128.0	75.8	65.7	59.0	81.3	51.0	62.0	76.7	155.4	209.5
Sectional E%	42.6	50.6	52.4	21.0	53.3	59.3	70.5	49.6	42.2	40.4	36.5	37.5
Hydraulic Loading on 3 Foot Section												
MGAD	40.0	55.9	71.9	87.8	103.9	119.9	119.9	119.9	119.9	199.8	51.94	71.91
MGAFD	13.36	18.63	23.96	29.30	34.63	40.0	40.0	40.0	40.0	66.59	17.31	23.97
Loading Ratio #/MG	792	896	1068	632	548	492	678	426	517	640	1297	1748
Filter E	79.5	79.7	89.1	90.8	88.3	94.9	94.1	92.1	80.3	74.8	80.4	70.6

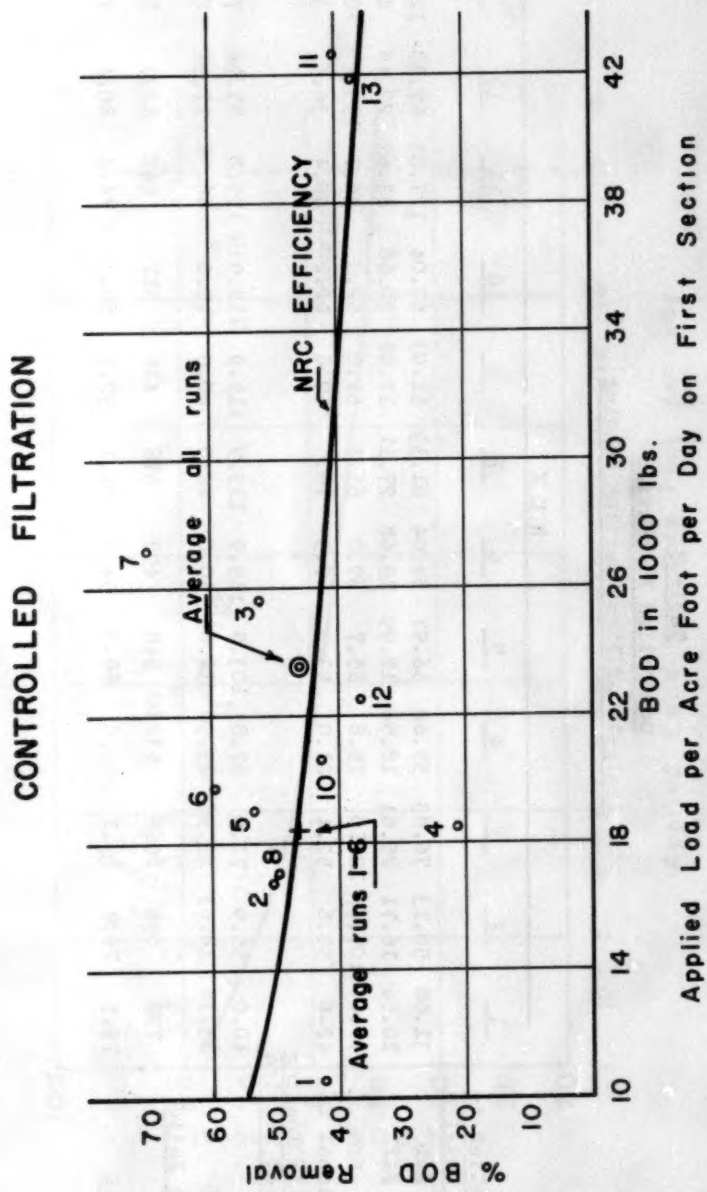
CONTROLLED FILTRATION
% BOD Removal
70
60
50
40
30
20
10
10
14
18
22
26
30
34
38
42
Applied Load per Acre Foot per Day on First Section
BOD in 1000 lbs.
NRC EFFICIENCY
Average all runs
Average runs 1–6
1
2
3
4
5
6
7
8
10
11
12
13

Figure 3

be plotted through the averaged points of per cent BOD remaining. The first break occurred at the bottom of section 3, the second at the bottom of section 5, the approximated k value for the first three sections being 0.096 and for the first five sections 0.111. It should be clear that each section actually had a different k value when calculated.

k values were also computed with the assumption that 95 per cent of the BOD applied during all runs was removable. (Figure 4) The approximated k for a line connecting beginning and depth points varied from 0.044 in Run 2 to 0.098 in Run 6, with the averaged k for all runs 0.065. If it could be assumed that all BOD was removable the k values for the first six runs ranged from 0.0382 to 0.0669.

The k value computed by Velz for low rate filters was 0.175 and for high rate filters 0.1505 with the assumption that L, the removable fraction, was 90.0 per cent and 78.4 per cent respectively. The k value for first section during Runs 2, 3, 5, and 6 closely approximated that of Velz for high rate filters. The L value, therefore, without some fundamental difference in filter performance below the first section should have been 0.784 for those runs. It is to be noted that the above performance occurred at hydraulic loading rates of 55.9, 71.9, 103.9, and 119.9 mgad, with corresponding organic loading of 1.22, 1.75, 1.68, and 1.71 # sfd. Filter liquor during three runs was about 23° C and the fourth about 20° C.

The performance of the first section is that which might be anticipated according to Velz' theory. However, organic loadings during these runs were well above the suggested upper limit of 1 # sfd at 20° C, and hydraulic loadings were from 2.8 to 6 times the rate of 20 mgad used by Velz. Under these loading conditions, the removable fraction should have decreased whereas the reverse was apparently true since total filter removal efficiency rose for the runs, the values being 79.0, 83.7, 87.5, and 89.1 per cent for Runs 2, 3, 5, and 6.

The controlled filter was operated for the first six runs as a single stage filter with all waste applied to the top of the filter. According to the Mississippi Valley standards for single stage filters [1] maximum dosage should be less than 4 mgad with less than 653.4 # afd BOD. Run 6 dosed at 20 times this rate hydraulically and averaged 6.4 times organically at a temperature of 20° C+. Run 11 dosed hydraulically at over 33 times the rate and organically 10.4 times the rate. The average removal efficiency for all runs was for practical purposes within the limit allowed by Curve C of the Standards which permits 23 per cent BOD remaining in the settled effluent. Run 3 efficiency was better than Curve B (18 per cent). Removals during Runs 4, 5, and 6 were better than Curve A (14 per cent).

Sectional application to two sections (Runs 7 and 8) had the effect of increasing both hydraulic and organic loading while maintaining efficiency of removal higher than Curve B. Total surface loading averaged 39.5 times hydraulically and 8 times organically that of the standard filter during Run 7, with an efficiency of BOD removal of 92 per cent. Run 8 loadings averaged 43.9 times hydraulically and 6.8 organically with an efficiency of 86 per cent.

Three section application permitted still higher loadings without excessive sacrifice of efficiency. Run 10 with a total averaged loading of 199.9 mgad and 2.56 # sfd (49.8 and 10.6 times standard filter loadings) maintained a removal efficiency of 81 per cent (better than Curve C).

CONTROLLED FILTRATION PERFORMANCE

Approximate BOD Removal Rates Based on Influent and Effluent Observations on Filter Profiles

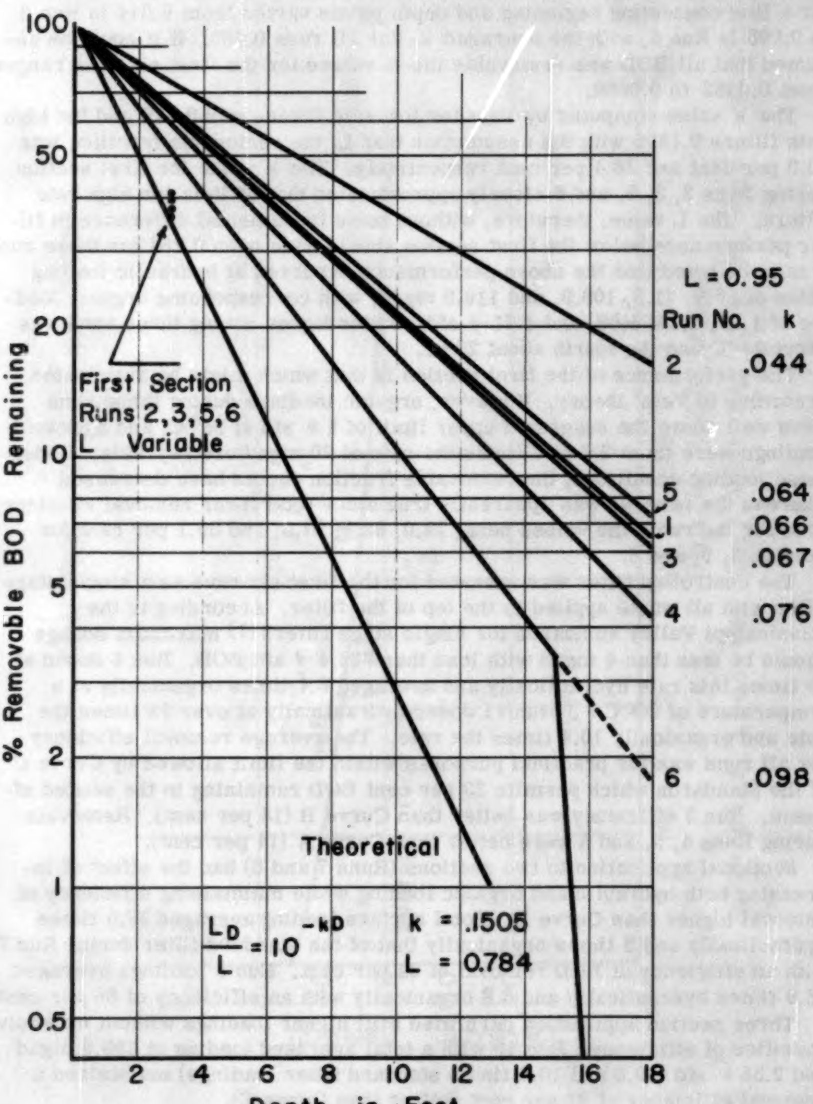

Figure 4

Stronger wastes were used during Run 12. After allowing the filter time to adjust the loadings averaged 95.9 mgad and 3.03 # sfd or 24 and 13.1 times standard filter loading with removal efficiency of 84 per cent. The maximum organic loading was obtained during Run 13 when an attempt was made to break the filter. This run was not as long as the others, but there was every indication that the filter was capable of readjustment to loading averaging 5 # sfd and reaching 7.5 # sfd during the run. On the fifth day of the run with a loading of 4.1 # sfd (16.1 times standard filter), the efficiency was 88.1 per cent. Table 8 demonstrates sectional information obtained from five profiles of the filter during Run 12. (Figure 5)

A brief comparison of controlled filtration performance with that of high rate filters illustrates that loadings both hydraulically and organically are higher on the controlled filter with corresponding higher BOD removal. From the Mississippi Valley standards, it may be assumed that 20 mgad and 1,300 # afd may be applied and that 70 per cent BOD removal may be expected. All filter runs, regardless of loading condition, produced averaged effluents of higher quality. Minimum hydraulic loading was twice and at maximum was ten times that of the above standard. Organic loadings began at 1.5 times and reached 10.5 times the standard.

It becomes obvious that limitations now applied to trickling filter design need to be revised upward for application to controlled filtration. When the control principles advanced here are employed, great flexibility in filter construction becomes possible. Depth can be increased by adding additional independently supported sections. Loading can be controlled by sectional feeding.

No indication of filter breakdown was experienced during the period of observations so the upper limits for both hydraulic and organic loading have not been established by these studies. It is apparent that filter sizing and area requirements can be reduced materially by using controlled filtration.

Stabilizing sections following feeding sections allow control of effluent stability. The data suggest that at least 9 feet of depth be provided for stabilization purposes.

Well oxygenated effluent can be obtained with the method of air application without the development of filter back pressure of consequence. At high continuing flow there is no problem of filter pooling or clogging. The slime layer on filter media is thin and active and appears to adjust readily to the conditions of feed. When filter liquor temperatures were between 16° and 25° C, organism growth appeared to be prolific and seemed to be more affected by loading conditions than by minor temperature changes. Certainly well-organized investigations of organism functions in controlled filter purification can be the subject of future study. It does appear that the maintenance of reasonable warmth in the filter during the present investigation accomplished the purpose of securing favorable temperature habitat for filter biota. Such temperatures can be maintained practically by enclosure or by the injection of warm air into an insulated filter.

Short circuiting in a filter of the depths used or deeper is a minor consideration. Downward liquid flow with counter-current air flow assures an intimate contact of oxygen-bearing air and filter water. Eventually, the aerated water will pass over filter media surfaces and aerobic growth conditions are possible at all depths. Such conditions were established within three feet of the lowest sewage application point in all runs. By distributing

Table 8

Controlled Filtration

Average of 5 Profiles

RUN 12

Filter Section	BOD ppm	D.O. ppm	Flow MGAD.	Organic Loading #AD	BOD % Removed
1 Top	155.4	0.0	51.94	67,380	
Bottom	98.6	0.04	51.94	42,750	36.5
Add Sewage	155.4	0.0	28.76	37,320	
2 Top	118.8		80.70	80,070	
Bottom	72.6	0.04	80.70	48,900	38.9
Add Sewage	155.4	0.0	15.18	19,680	
3 Top	85.7		95.88	68,580	
Bottom	60.2	0.46	95.88	38,180	29.7
4 Top	60.2	0.46	95.88	38,180	
Bottom	42.6	1.82	95.88	34,080	29.3
5 Top	42.6	1.82	95.88	34,080	
Bottom	35.4	3.12	95.88	28,320	16.9
6 Top	35.4	3.12	95.88	28,320	
Effluent	30.4	3.54	95.88	24,330	14.1

Average E = 80.4%

CONTROLLED FILTRATION

Sectional Application of Settled Sewage

Average of 5 Profiles

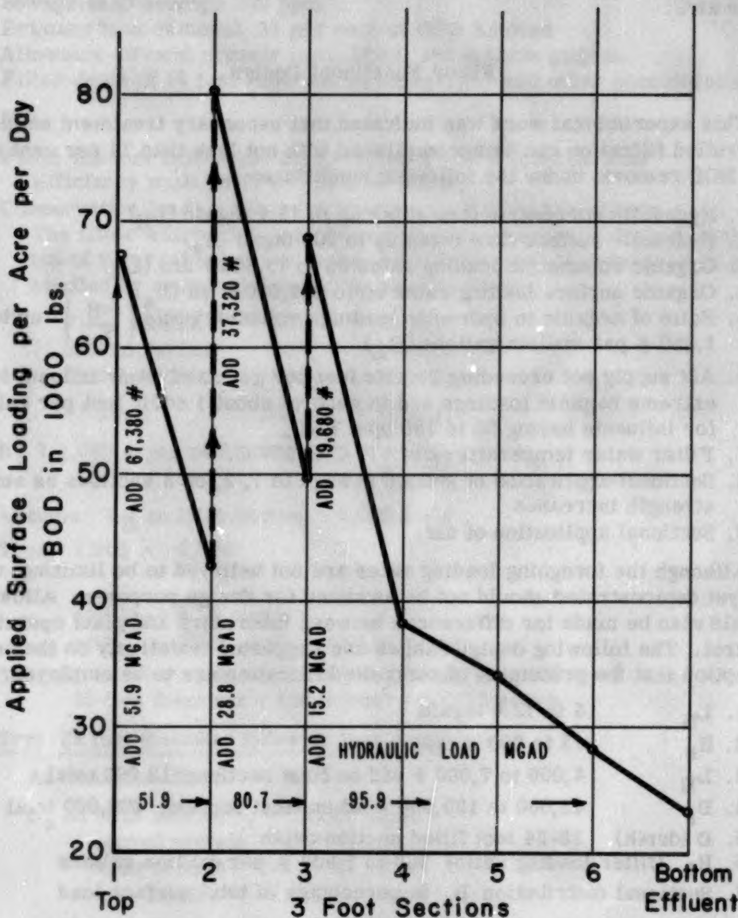

Figure 5

approximately 50 per cent of the total air flow to the bottom of the sections receiving sewage and by distributing the remainder to the bottoms of the remaining sections, a satisfactory dissolved oxygen condition for the maintenance of aerobic growth in the filter was obtained. The actual proportioning of air to the sections is subject to analytical determination and plant adjustment to meet demands of the sewage. It is known from the experimental work that total air flow of about one cubic foot per gallon of sewage is adequate for treatment of settled domestic sewage having up to 200 ppm BOD. It is possible that less air would suffice. It is important in the concept of controlled filtration that filter air intake be positively controlled. A tight filter trapped at the effluent point and open at the top is also essential to positive control of filter air.

Filter Functional Design

This experimental work was indicated that secondary treatment employing controlled filtration can be accomplished with not less than 74 per cent average BOD removal under the following conditions:

1. Hydraulic volumetric flow rates up to 12.4 mgafd (L_H)
2. Hydraulic surface flow rates up to 200 mgad (H_s)
3. Organic volumetric loading rates up to 13,800 # afd (L_B)
4. Organic surface loading rates up to 222,000 # ad (B_s)
5. Ratio of organic to hydraulic loadings volumetrically $\left(\frac{L_B}{L_H}\right)$ up to 1,850 # per million gallons (R_L)
6. Air supply not exceeding 2 cubic feet per gallon of filter influent for extreme organic loadings and in general about 1 cubic foot per gallon for influents having 50 to 130 ppm BOD
7. Filter water temperatures of 17° C to 25° C.
8. Sectional application of settled sewage to 1, 2, or 3 sections as sewage strength increases
9. Sectional application of air.

Although the foregoing loading rates are not believed to be limiting, values not yet demonstrated should not be assumed for design purposes. Allowance should also be made for differences between laboratory and plant operating control. The following design ranges are suggested tentatively on the assumption that the principles of controlled filtration are to be employed.

1. L_H 4 to 12.4 mgafd
2. H_s 72 to 200 mgad
3. L_B 4,000 to 7,000 # afd on first section; 12,000 total
4. B_s 43,000 to 120,000 # ad on first section; 200,000 total
5. D (depth) 18-24 feet filled section depth
6. R_L (filter loading ratio) 500 to 1,800 # per million gallons
7. Sectional distribution B_s in percentage of total surface load

	Section 1	Section 2	Section 3
1 section application	100.	-	-
2 section application	65 - 70	Up to 35	-
3 section application	55 - 60	Up to 30	Up to 15

Obviously within the ranges stated there is great flexibility in design, useful in meeting physical and topographical limitations of plant site and variations in plant daily flow and in sewage strength. For example, a portion of filter liquor may be returned to increase flow and decrease the BOD of influent or flow may be maintained on the top section and variable flow added to the next one or two sections during periods of peak flow.

A sample design will serve to illustrate a number of flexibility points and the use of filter loading ratio as a basic design tool.

ASSUME:

Average flow 1 mgd
Sewage BOD average 200 ppm
Primary tank removal, 35 per cent of BOD Applied
Allowable effluent organic load, 250 # per million gallons
Filter depth of 18 feet required by topography and other considerations

THEN:

Filter influent BOD = 130 ppm = 1,085 # per million gallons
Efficiency must be 77 per cent or higher
Conservative loading rates for average flow should be chosen.
The filter will be designed for application of average daily flow to top of filter. Peak flows (assumed 180 per cent of average) will be handled by sectional application in proportions:

First section	60 % =	1.08 mgd
Second section	30 % =	.54 mgd
Third section	10 % =	.18 mgd
Total	100 % =	1.80 mgd

$$R_L = 1{,}085 \text{ \# per million gallons} = \frac{\text{\# afd}}{\text{mgafd}} = \frac{L_B}{L_H}$$

Assume: L_B on first section = 6,000 # afd

$$\text{Then: } 1{,}085 = \frac{6{,}000}{L_H}$$

and L_H = 5.53 mgafd
or H_s on first section = 99.54 mgad
Therefore, filter area required = 0.0108 acres = 470 feet^2
25 feet diameter = 490.0 feet^2 = 0.0113 acres

<u>Try:</u> <u>25 foot diameter filter 18 feet deep</u>

At maximum flow:

H_s on first section	=	95.58 mgad
second section	=	47.79 mgad
third section	=	15.93 mgad
Total	=	159.3 mgad

60 %	B_s on first section	= 103,700 # ad	L_B =	5,760 # afd
30 %	second section	= 51,850 # ad	=	3,460 # afd
10 %	third section	= 17,280 # ad	=	1,440 # afd
	Total	= 172,830 # ad	=	10,660 # afd

Check condition of minimum flow on first section

Assume flow = 0.7 average daily flow = 0.7 mgd

H_s = 61.94 mgad

B_s = 67,200 # ad

L_B = 3,730# afd

Check condition of average flow on first section

Flow = 1.0 mgd

H_s = 88.5 mgad

B_s = 96,400 # ad

L_B = 5,350#afd

Filter, sizing, and loading conditions are compatible with the suggested criteria except at minimum flow. The deficiency is not serious enough to cause concern

A standard filter six feet deep to meet approximately the same removal requirements demonstrated in the above example would require 24 times the area and 8 times the rock volume. A high rate filter five feet deep would require approximately 14 times the area and 4 times the volume.

Observations

On the basis of the present studies, it may be presumed that application of controlled filtration principles makes possible the functional design of trickling filters greatly reduced in filter area and volume. Such filters are capable of producing effluents of quality equal to or better than that required by present standards.

First section performance of controlled filters is comparable with performance of other high rate filters. Thereafter there are basic differences.

No reliable limiting relation or removal of BOD to either organic load or hydraulic load was found during these studies.

Depth of filter, sectional construction, sectional application of both sewage and air, and filter water temperature have a bearing on successful treatment at high rates and on the provision of a favorable habitat for sewage biota.

It is essential that continuous flow be maintained to obtain the higher rates of organic removal. Continuous and constant flow combined have produced the best filter performance.

The filter loading ratio R_L provides a simple basis for computing filter size. It is the sewage strength expressed in terms involving depth of filter, area of filter, quantity of sewage, and weight of biochemical oxygen demand.

ACKNOWLEDGMENT

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An expression of appreciation is only a token acknowledgment of the countless hours of work and monitering of equipment by John Bevan, Research Associate. Dr. Gail P. Edwards was most helpful particularly

in examination of many specimens of filter growth and as a colleague available for discussion of unusual results.

The research was conducted with the support of the Pacific Flush Tank Company of Chicago, Illinois.

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WASTE DISPOSAL AS RELATED TO SITE SELECTION

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(Proc. Paper 1000)

SYNOPSIS

The rapid increase in the atomic energy industry has produced many problems with regard to site selection, the primary problem being waste disposal. The paper discusses the waste disposal problems at various AEC installations and efforts made for their solution.

The selection of a site for an atomic energy plant is one of the most important decisions management has to make. This is because the site selected profoundly affects (1) the layout and design of costly structures and facilities, (2) the pattern of future expansions, (3) the day-to-day operations and (4) in case of unforeseen incidents, the safety of employees or persons and property in the vicinity of the plant. These are important factors in company policy, finance and public relations.

In this new and rapidly expanding industry, perhaps more than in any other, decisions as to the site for a plant or an integrated group of plants focus to a major degree on the character and quantities of wastes which it is expected will or might be released. This is particularly true in the case of nuclear reactors and associated chemical processing plants where levels of radioactivity in product and wastes are high. With modifications, it also holds for feed material processing and nuclear fuel fabricating plants, research laboratories and other places where materials having lower levels of radioactivity are used.

The purpose of this paper is to present some of the more significant relationships between plant site selection and waste disposal which have been brought out by experience in dealing with problems in waste disposal and environmental sanitation at various production and research installations operated under the Atomic Energy Commission.

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Early Experiences

During World War II the sites selected for government owned atomic energy plants were in more or less isolated areas.[1] This selection was partially for reasons of security, but availability of power and water were also major considerations.

In the interim period there has been opportunity to evaluate the results of performance and practice; new plants have been built and old ones have been refitted. Much has been learned which now can be put to use by privately owned industry as the atomic energy industry moves into a new era of peaceful service.

Looking Ahead

Under the relaxations of security regulations as to availability of technical information and authorization for wider uses of nuclear materials given in the 1954 Atomic Energy Act,[2] the interests of private industry in exploring the opportunity to use atomic energy have been pronounced. It seems likely that the interests which will organize and finance these ventures in an open competitive field will want to locate their plants at strategic places in relation to the market for their product and services. This will be reasonably near populated areas—just the reverse of the situation which presented itself when sites were being sought for the government wartime atomic energy plants. It will be helpful to discuss some of the realistic situations which a company wishing to build a new plant to use atomic energy or to manufacture a product using radioactive materials must face today when it seeks a site for this new enterprise.

Public Concern Over Radiation

One of the first considerations will be the possible concern of the citizens of nearby communities to hazards—real or imaginary—which a plant using nuclear energy may bring to their area. This possibility presents a delicate problem in public relations. While normally most public officials welcome the coming of new industries to their areas, in the case of a plant using nuclear materials, they may show some concern as to the future impact of this new industry on the health and safety of their people and the environmental assets of their communities. This is entirely understandable.

Experience has shown that the greatest concern of public officials over the location of atomic energy plants within areas of their jurisdiction is in regard to storage, release or disposal of radioactive wastes. The interest which the public now shows in clean streams, preservation of recreational areas, protection of surface and underground sources of water supply and clean air is a sign of healthy progress in environmental sanitation. It may also be a portent of trouble ahead for any new industry which is shortsighted in not planning to meet reasonable requirements to reduce hazards related to disposal of its waste. On the other hand, unreasonable demands on industry as regards the degree of clean up of waste could seriously affect the interest of the industry and the community or region where a new industry proposes to locate.

Unique Properties of Radiation

Radioactive wastes may be in the form of solids, liquids or gases and at times in intermediate states as colloids. The problems associated with disposal of radioactive wastes are unique. The effects of radiation can be immediate or delayed. Radiation is an insidious contaminant with cumulative damaging effects on living cells. Certain highly active radioisotopes continue to give off energy over long periods of time—several generations of the human race. This is a reality of profound importance in evaluating risks and in establishing protection against them. It is a factor never to be forgotten in selection of a plant site and in release or disposal of radioactive products and wastes to the environment.

Disposal of Wastes

High Level Radioactive Wastes

High level wastes may contain as much as 10^{2} curies per liter. Under normal operations their principal source is in the processing of irradiated fuel elements. The cost[3] of treatment and disposal of these wastes are high.

If nuclear power is to compete favorably with other fuels cheaper methods of waste disposal must be found. Cutting of costs must be done intelligently for otherwise it might involve risks which could present environmental hazards and reflect unfavorably on the industry.

Disposal policies are especially important in the case of high level radioactive wastes which contain long lived and biologically significant fission products[3] such as Sr^{90} and Cs^{137} and others of shorter half life such as Ce^{144}, Ru^{103} and certain isotopes of rare earths which may be difficult to control when released to soils.

Future Significance of Waste Problem

As the industry grows the dilution required to dispose of high level long-lived radioactive wastes to the environment to meet permissible concentrations in air and water for continuous exposure of humans could be fabulous. W. Kenneth Davis,[4] Director of the Atomic Energy Commission Division of Reactor Development, in a paper[5] before the American Power Conference in Chicago in April 1955 estimated that the capability of nuclear power in service in the United States would be:

By the end of	Million Kw
1960	2.0
1965	5.0
1970	27.0
1975	83.0
1980	175.0

This power would of course be the output of many reactors probably widely distributed. The estimated rapid rate of increase, however, is striking and serves to give some indication of the importance of resolving the problems of disposal of long-lived and hazardous radioactive wastes.

In the fissioning of one gram of uranium one megawatt day of nuclear heat energy is released and about one gram of fission products is formed.[5] One year after removal from the reactor, assuming continuous uniform operation, one gram of fission products would have a heat power level of about one watt or the equivalent of 500 curies of radioactivity. For the above 1980 rate of capability of nuclear power the fission product production for one year would require in the order of 1.85×10^{18} gallons of water to dilute Sr^{90} (yields 5.3 percent) to safe life time drinking water levels. This is approximately equivalent to the average annual flow of the Mississippi River prior to flood diversion 100 miles above its mouth for a period of 12,600 years.

Fixation on Soils

Nature provides some potentialities for resolving environmental problems. These are being studied in order that they may be taken advantage of in reducing the cost of disposal of wastes from chemical processing of spent fuels from other sources. Fortunately certain soils and the suspended and bed loading of most waterways have properties of absorption or adsorption of radioactivity. The exchange capacities of soils for radioisotopes can be seriously affected by other non-radioactive ions in wastes. This complex should be fully evaluated in deciding on the degree of pre-treatment which is required before wastes are disposed to the ground. The heat in high level waste resulting from gamma radiation introduces an important problem in the disposal of these wastes.

Research in ground disposal is under active investigation at the Oak Ridge National Laboratory as an important environmental problem associated with the development of future reactors for power production. Consideration is being given to the feasibility of disposal of these wastes to deep wells or to deep cavities existing naturally or made by dissolving salts from deep dry deposits. The Earth Sciences Division of the National Research Council is also co-operating in this program.

The requirements of environmental protection could be met by fixing radioactivity in columns of selected and pretreated clays or other suitable material and then raising the temperature sufficiently to form a solid ceramic mass from which the wastes could not be elutriated or leached. Such a mass could then be buried in a tight soil designated by a geologist as suitable for waste storage. Research to determine feasibility and cost of such a method is underway at the Brookhaven, Oak Ridge and Los Alamos National Laboratories.

Separation of Significant Isotopes

Another possibility of lessening the environmental hazards associated with the disposal of high level radioactive wastes is to remove the long-lived and biologically significant isotopes from the wastes prior to disposal. If this were done disposal to the ground in selected areas could be carried out with greatly reduced environmental hazards.

Land Burial

Burial is an economically attractive method of disposal of solid wastes but it presents some serious environmental problems. The selection of burial grounds should be made in co-operation with an experienced geologist.

Designated burial grounds should be fenced and be well identified. Burial grounds should be a minimum in number as they are dedicated areas often so contaminated as to pre-empt for all practical purposes use of the land for other services for very long periods of time.

Underground Tank Storage

Underground storage without fixation of the hazardous long-lived radioisotopes could have long term implications affecting the welfare of future generations. Waste burial grounds and underground storage tanks should be located so that in case of leakage pollution of ground water may be minimized. Preferably, they should be set well above the water table and in tight soils from which movement of any leakage would be slow. Provision should always be made for periodic monitoring in the vicinity of these storage areas to detect any leaks.

Storage of high level radioactive wastes in underground tanks as currently practiced has the advantage of confinement, thus providing time for decay of radioactivity. Provisions to remove heat from tanks often is required and it is costly. Tank storage is not an ultimate solution of the waste disposal problem. The wastes may be radioactive for a century or more whereas the tanks in which they are stored may be expected to corrode and leak in a matter of decades. Obviously, therefore, this method of handling still involves a potential environmental hazard.

Low Level Wastes

The release of low level radioactive wastes from the atomic energy industry also presents environmental problems. These wastes are those whose activity is 10^3 or 10^4 in excess of permissible long term limits of exposure for humans. Because the quantities involved are very large, where conditions are favorable for dilution in the atmosphere, in surface waterways or to the ground, such disposal is economically attractive and has possibilities.

Extensive research in determining the significant parameters in making appraisals of favorable dilution factors in nature is being carried out under Atomic Energy Commission contracts with the Weather Bureau, the Geological Survey and several large universities. In addition, staff of the Atomic Energy Commission and its operating contractors at the Hanford Works in Washington, the Knolls Atomic Power Laboratory near Schenectady, the National Reactor Testing Station in Idaho and at the Brookhaven, Argonne and Oak Ridge National Laboratories are conducting similar research in this field.

Disposal in Remote Areas

It is reasonable to assume that within the next decade atomic energy plants may be built in remote places throughout the world where the need of power for special purposes is so important that the factor of cost may not be too significant. Here again the industry has a real obligation to maintain high standards of safety and environmental sanitation. Even though initially exposure of people and property in these remote areas may be slight a reckless or capricious attitude in disposal of long lived wastes should not be permitted. With the advancement in travel and transport to these areas and perhaps unpredictable uses of their natural resources, a careless practice

in this generation in the interest of low costs could pre-empt or penalize the use of these resources by future generations. History is replete with examples of the penalities which subsequent generations have paid for the reckless, uncontrolled actions of its forefathers.

Plant Enlargements

In site selection, serious consideration should be given to the possibility or probability that a plant as originally built may be enlarged, or its functional processes changed with relatively greater hazard. When a plant or site planned for one purpose is put to a new use it is important that such basic services as utilities, waste disposal systems and points of release of waste effluents be re-studied to ascertain their adequacy for the newer use. Such modification should be discussed with public officials responsible for public health and safety in the area. If the original plant was served by public utilities such as water, power, sewers and other drainage facilities this obligation is all the more pressing.

Considerations in Site Selection Problems

The selection of a site for an atomic energy plant calls for the integrated judgment of competent people in a variety of professions. These might include: nuclear, health and bio-physicists; physical and nuclear chemists; structural and ground water geologists; nuclear, chemical sanitary and safety engineers; industrial hygienists; ceramists; biologists; mineralogists and soil scientists; meteorologists, hydrologists, public planners and others. Important among the assignments on which these specialists should be prepared to assist are the: (1) selection of sites for various units of a plant making the best use of area topography and environmental conditions, (2) availability of water for process and domestic purposes, (3) type, capacity and location of waste storage and treatment facilities, (4) degree of waste treatment required initially and later in a progressive expansion program, (5) points and methods of discharge of waste effluents, (6) sites for burial grounds for radioactive and toxic wastes, (7) dilution factors in nature which could be taken advantage of in disposal of wastes, (8) selection of significant monitoring points for establishing environmental background information and subsequently the effect of day-to-day operations on background, (9) developing a program for evaluation of environmental hazards in case of a serious accident or spill, and (10) prompt notification of public regulatory officials so that proper warning may be given to off-site populations and industries.

Geology

The geology of a site for an atomic energy plant should be very carefully studied in advance of selection or planning of on-site structures. The depth and character of over-burden and the elevation at which rock may be encountered are important in evaluating costs of excavation and the design of foundations. They also are important in establishing the location of underground waste storage structures such as tanks and waste disposal facilities such as wells, cribs, lagoons and burial areas. The capacity of the soils to receive and to absorb or adsorb radioisotopes which are in the waste stream should be determined. This can be done by column studies using material from carefully removed boreings.

In soils in which pipes for transmission and tanks for storage of liquid wastes are contemplated exact information should be obtained as to the corrosiveness of the soils and the existence of conditions favoring electrolosis. For large structures and underground tanks and piping knowledge of the history of an area as to frequency and intensity of earthquakes is important.

The deeper the water table usually the more satisfactory are conditions for release of radioactive wastes to the ground. It is important to know the porosity of the sub-strata in order to be able to establish the rate of flow of ground water and liquid wastes. The elevation, direction and rate of flow of ground water are essential to decisions as to disposal of wastes to the ground.

Hydrology

For a new industry with unique wastes and a need for large quantities of water for heat exchange and miscellaneous processing of materials, it is essential that studies of the hydrology of the region and area under consideration for a new site be thorough. Hydrologic investigations should include a listing of all restrictions in the use of water from available sources, upstream uses who do or may contribute wastes to the streams under consideration and downstream uses of water who may be affected by radioactive or toxic wastes which may be planned or those which might be released by an accidental spill. The stream and bed loading may be highly significant in a waterway used for disposal of radioactive wastes. Impoundments with reduction in velocity of flow may provide areas where radioactivity held by suspended matter in the stream may deposit. If so, the effect of sharp increases in run-off inbringing this settled material in suspension again should be ascertained. The biological characteristics of the stream may have a profound influence on the uptake of radioactivity.

Meteorology

The meteorology of a site or areas has an important relationship to plant design and operation (Refer to Mr. White's paper).

Evaluating Hazards

Under normal operations waste products from a reactor or chemical processing plant operating on a continuing basis can be predicted and a program for on-site decontamination planned so that the ultimate dilution of radioactive gaseous or liquid effluents released will be such as to assure no environmental exposures of significance. But in selecting a site for such plants it would be unrealistic to assume that operations will always be normal. In an evaluation of environmental hazards, it would be prudent to make certain pessimistic assumptions.

Problems in site selection for nuclear reactors for power production and chemical processing plants will require much consideration because at these plants the levels of radiation are high and the quantities of radioactive materials used are substantial.

In general what has been said of reactors and chemical processing plant applies to such plants as those for fuel processing, fabrication of fuel assemblies and research laboratories. Usually, however, the specific activity of the wastes are much lower and the hazards proportionately less. In all cases, however, it must be recognized that handling radioactive materials

constitutes certain hazards of exposure to plant employees and to people in the environs of the plant. These plants, and chemical processing plants also use large quantities of toxic chemicals such as fluorides and nitrates. Their use, storage and disposal requires special considerations as to environmental hazards. Through good planning and careful housekeeping operations at these plants can be made entirely safe.

The use of radioisotopes in medical, biological, agricultural and industrial research is becoming widespread and the selection of sites for work of this kind also requires careful consideration as to disposal of wastes.

Insurance Considerations

Management of most industries seek some form of insurance coverage against accidents which may affect their employees, their plants and facilities and the lives and property in the environs of their plants. At plants using atomic energy the insurance problem is complicated. The backlog of experience is small by which to establish a probability of occurrence of a major accident. The gross potentialities of an incident and its aftermath especially for reactors and chemical processing plants present reasons for concern.

The alternative to selecting a site which involves remote environmental hazards in case of a serious accident is to confine the reactor within a tight shell strong enough to withstand an explosion and prevent loss of fission products and other hazardous materials which might be released. An example is the steel sphere 225 feet in diameter and nearly an inch thick which encloses the submarine test reactor at West Milton, New York. The additional costs of providing such protection for a small research or a large power reactor may be less than that of locating the facility a greater distance from the area the reactor is to serve.

In conclusion, there is good evidence with careful planning plants for the use of atomic energy for peaceful purposes can be located reasonably near populated areas. This new industry can avoid the mistakes of other great industrial enterprises of the past where too often early enthusiasm for expansion shaded judgments in site planning to the detriment of all.

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METEOROLOGY AS RELATED TO REACTOR SITE SELECTION

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(Proc. Paper 1001)

SYNOPSIS

The routine release of radioactive gaseous wastes as well as the possibility of an accidental release of large quantities of this waste material is discussed in relation to site selection. The main meteorological parameters of wind direction and speed, atmospheric stability and precipitation are also discussed. Some atmospheric diffusion formulae are presented to help assess the problem of site selection.

INTRODUCTION

The development of atomic energy into a major technological activity presents an important challenge to the ingenuity of meteorologists, especially in connection with site selection and operation of reactor facilities. Radioactivity, when confined and properly shielded, is of direct concern only to the persons in the immediate area. It is not until it escapes or is released into the air that the location of the site with respect to its surroundings becomes extremely important. Since the atmosphere is the most mobile of all geophysical media and can transport radioactivity swiftly over large areas, meteorology assumes particular importance in the site selection and hazard analysis of proposed atomic energy installations.(1) Since it is evident to the meteorologist that certain locations,(2) because of their geophysical or physical location, may expect to receive large concentrations of pollutants, it is a recommended practice to evaluate the air pollution potential, or the dilution efficiency of the atmosphere at prospective locations before making a final decision on just where the plant will be located.

In assessing the requirements for an atomic energy site, one must clearly understand the final plant design. Chemically toxic radioactive waste gases may be produced by a nuclear reactor through the irradiation of cooling air or the periodic removal of fission product gases and their release to the air.

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1. Weather Bureau, U. S. Dept. of Commerce, Washington, D. C.
2. Same as above.

Laboratories handling radioactive materials may also find it necessary to vent their hoods and working spaces. Large chemical plants preparing or reprocessing nuclear fuels may be forced to dispose of large quantities of fission gases and they may also be required to use and release toxic chemicals in gaseous form. The evaporation of radioactive liquid wastes may cause a waste "burial ground" to be a source of gaseous contaminants. Incineration of radioactive solids can also contribute to gaseous products. The method of release of these gases is almost as numerous as the sources. They may be deliberately exhausted through stacks or vents, they may inadvertently leak from containers or buildings, or they may be evaporated from water surfaces. For most of the reactor power plants that are now in the process of being developed only very limited quantities of radioactive off-gases will routinely be released, but any proposed site must be evaluated mainly for a possible accidental rupture of the containment vessel. However, other atomic energy installations may be operated by industry within the next few years that will require daily disposal of radioactive waste gases. Sites for this type of facility must be examined from the consideration of the immediate environment.

It is well realized that meteorology is not usually a primary factor in the selection of a new site. As is well known, many factors such as markets, raw material, water and power availability, labor and construction costs must be considered, all of which may be more important than the weather effect. However, somewhere along the line, the problem of waste disposal, either as it affects the streams or the atmosphere, must be evaluated.[3] In the case of radioactive wastes from a nuclear plant, meteorology is usually given slightly more consideration.

Meteorological Parameters

Those meteorological parameters which should be considered at locations where atmospheric effluents will or may be released are the wind direction and speed, the atmospheric stability as given by the vertical temperature distribution (called lapse rate), and the precipitation records. The data on wind and stability are usually analyzed to give a picture of average conditions and the variation with time of day and with season. Fig. 1 is an example of this type of presentation. Fig. 2 presents an annual distribution of lapse rate versus time of day. Such a graph is obtained by averaging the lapse rate for each hour for the four seasons and the constructing isopleths of equal lapse rates. Another useful statistic is the duration of temperature inversions (increase of temperature with height). These particular data are probably the most useful in comparing two alternate sites from the standpoint of utilizing the atmosphere for disposal of gases. A site where the bias is toward populated areas would be less adaptable to gaseous waste disposal than one where inversions were less frequent and persistent. It must, however, be noted again that the meteorological factors considered alone will seldom permit a categorical determination of the suitability of a site. The type of plant operation must certainly be considered. In the case of persistent inversions mentioned above, if a particular plant has sufficient storage capabilities, and if the toxic levels are low enough, a large proportion of inversion conditions may not be a serious drawback to the location of the plant at this site. Certainly, however, the increased concentrations that might result under unfavorable meteorological conditions must be examined before such a decision is reached.

Meteorological Diffusion

The evaluation of the numerous influences that affect the dispersion of gases in the atmosphere requires some type of coherent mathematical statement containing parameters that respond to physical changes of the atmosphere near the source and, in addition, that can be applied to sources in widely differing locations. There are several mathematical treatments of diffusion in the atmosphere, no one of which seems to satisfy all of the variables that may influence diffusion. However, the development and formulation due to O. G. Sutton of England[4] have been applied to the dispersal of stack gases at many of the Atomic Energy Commission sites in the United States. Sutton's instantaneous point source formula is:

$$\chi_{(x,y,z,t)} = \frac{Q}{\pi^{3/2} C_x C_y C_z (\bar{u}t)^{3(2-n)/2}} \exp\left\{-(\bar{u}t)^{2-n}\left(\frac{x^2}{C_x^2} + \frac{y^2}{C_y^2} + \frac{z^2}{C_z^2}\right)\right\} \quad (1)$$

where x, y, and z (meter) are coordinate axes in the downwind, cross wind, and vertical directions, Q is the source strength (curies, grams, etc.) u is the mean wind (meters/sec), t is time (seconds), C_x, C_y, C_z are "virtual diffusion coefficients" [(meters)$^{n/2}$] and n is a dimensionless stability parameter variable between zero and one with increasing values corresponding to increasingly stable atmospheric temperature gradients.

By integration, with respect to time, a formula for a continuous point source is obtained.

$$\chi_{(x,y,z)} = \frac{2Q}{\pi C_y C_z \bar{u} x^{2-n}} \exp\left\{-x^{n-2}\left(\frac{y^2}{C_y^2} + \frac{z^2}{C_z^2}\right)\right\} \quad (2)$$

By integration, with respect to direction usually cross wind (y-axis), an equation describing the concentration distribution downwind from a continuous line source results

$$\chi_{-(x,z)} = \frac{2Q}{\pi^{1/2} C_z \bar{u} x^{(2-n)/2}} \exp\left\{-\frac{h^2}{C_z^2 x^{2-n}}\right\} \quad (3)$$

where h = height of release (meters)

Figure 3a shows concentration isopleths calculated from equation 2 and 3b from equation (1).

Certain useful geometrical properties of diffusing clouds are easily obtained by differentiating and maximizing certain of Sutton's results.

The distance of the maximum concentration from the source (represented by d_{max}) for an instantaneous point source is

$$d_{max} = \left(\frac{2h^2}{3C^2}\right)^{1/(2-n)} \quad (4)$$

and for a continuous point source is

$$d_{max} = \left(\frac{h^2}{C^2}\right)^{1/(2-n)} \tag{5}$$

while (for the instantaneous point source) the maximum concentration at the point d_{max} is

$$\chi_{max} = \frac{2Q}{(2/3\, e\pi)^{3/2} h^3} \tag{6}$$

and for the continuous point source is

$$\chi_{max} = \frac{2Q}{e\pi \bar{u} h^2} \tag{7}$$

The cloud width, $2Y_0$, and the cloud height Z_0 are easily obtained from

$$2Y_0 = 2\left(\ln \frac{100}{p}\right)^{1/2} C_y\,(x)^{(2-n)/2} \tag{8}$$

$$Z_0 = \left(\ln \frac{100}{p}\right)^{1/2} C_z\,(x)^{(2-n)/2} \tag{9}$$

where p is any desired percentage of the axial concentration. These formulae represent one set of primary tools of the meteorologist in attempting to describe the travel and dispersion of gaseous wastes.

However, these formulae together with the parameters obtained by Sutton were developed under conditions which may differ greatly from those where the computations must be made. First and foremost, it must be remembered that the parameters were based on three-minute average concentrations. Secondly, the terrain over which the experiment was conducted was relatively smooth. And third, the equations were developed for neutral temperature gradient conditions. If these factors are always considered, the equations may be used with a fair degree of success, and the meteorological uncertainties are seldom greater than other factors such as the rate and amount of the effluent released.

It has been shown by Holland(5) that the diffusion coefficients may be modified experimentally to correspond to the site over which gaseous effluent is released. A more empirical approach was adopted by Church(6) in which the behavior of effluent plumes from more or less isolated stacks was classified according to appearance and the type of vertical temperature gradient that most usually accompanied the various plume types. These types and the accompanying temperature lapse rates(7) are shown in Fig. 4. In general, this approach requires qualitative adjustment to the diffusion formulae; however, it is possible to correlate plume-type behavior with the parameters of the equations and obtain concentration estimates correct to an order of magnitude.

Particular mention should be made of the behavior of waste gases from an elevated source under stable atmospheric conditions, since it is in these instances that the diffusion formulae are subject to the greatest error. Field experiments with visible smoke plumes show that when the atmosphere is very stable, effluent from an elevated source will travel for long distances with negligible vertical diffusion and only slow horizontal spreading. In fact, the horizontal spread is more the result of meandering variation in wind direction rather than of eddy dispersion of the plume. The plume, when viewed from above or below, resembles a long thin ribbon which widens very slowly with distance. The significance of this type of dispersion pattern is readily seen, since material released is diluted very slowly and concentrations aloft may remain high for several kilometers. Should this highly concentrated plume intersect higher terrain or be brought suddenly downward by precipitation, appreciable ground concentrations will be much greater than the predicted theoretical values.

In addition to choosing favorable meteorological conditions for the release of gaseous waste products, it can be seen from the formulae of (6) and (7) that the maximum ground concentration is inversely proportional to the height of the point of release. It is, therefore, desirable to vent the material through stacks that are as high as possible. However, there is a practical and economical limit to the height of a stack. In an attempt to extend the height of release without building prohibitively high stacks, use is often made of blowers to increase the exit velocity of the gas or heaters to increase its temperature, thus its buoyancy, and obtain additional height before lateral diffusion takes over. Before expensive equipment for heating or accelerating gaseous wastes is installed, it is well to examine the prevailing meteorological conditions since both the excess temperature and increased velocity of the exhausted gases are most effective when the horizontal wind is light. At a location subject to a persistent high wind speed, the gain in "effective stack height" from auxiliary equipment may be quite small.

Meteorological Observations

After a definite location has been chosen, more specific information can be, and usually is, obtained by the installation of a program of meteorological measurements at the site. This program will usually consist of records of wind, temperature, precipitation, and, if required, temperature lapse rates. The scope of such a meteorological program will depend on several factors; namely, the magnitude of the potential pollution sources, the size of the site, and the roughness of the terrain. A large site with many nuclear installations, or one in very irregular terrain, will require a more elaborate meteorological program to define the diffusion patterns than would a single laboratory located in a large level plain. The meteorological data may be of routine value in evaluating radiation measurements or for legal purposes in addition to engineering value for plant expansion.

Meteoroglocal Applications and Conclusions

Specific applications of meteorology to the problem of gaseous waste disposal will include two main fields, engineering design, and plant

operations. In the field of engineering design, meteorological information may be used to select a site that is favorable for the use of the atmosphere to dispose of waste gases. Information may be furnished on the placement and orientation of buildings at a site so that no one building is persistently affected by gases from another source. If the character of a site is such that lateral dispersion is limited, buildings may be spaced (based on the theoretical equations and actual meteorological data) to avoid points of maximum concentrations. If computations indicate that untreated gases will result in concentrations higher than desirable, meteorological data can be considered in the choice of stack heights sufficient to obtain tolerable concentrations without unnecessary expenditures. In this connection, it should be noted that information of the average height of temperature inversions may be quite valuable. If the majority of inversions lie below a reasonable height, stacks may be constructed to vent gases above the inversion, thus obtaining the increased dilution of the more unstable air aloft and utilizing the inversion barrier to prevent the downward spread of contaminants. Without precise meteorological information, it would be difficult to obtain such an advantage other than by chance. In addition to the use of tall stacks, the volume and/or toxicity of waste gases may be reduced by absorbers, filters, scrubbers, etc. The capacity of these devices may be fitted to the capacity of the atmosphere at a particular location and time to disperse materials. In applying meteorological data to plant operation, the meteorologist may be asked to compute concentrations resulting from specific operations; and, if necessary, a program may be instituted to control operations based on meteorological information. Such control could consist of limiting the effluent volume so that ground concentrations are kept below a certain value. Or, alternatively, the release of waste gases may be scheduled only for times when meteorological conditions favor the rapid spread and dilution of the released material. An initial survey of an area and the correlation of favorable diffusion conditions with specific indications of meteorological instruments may provide sufficient information. One such approach which would not necessarily require meteorological personnel has been described by Smith.(8) This work correlated the width of the wind direction trace with the temperature lapse rate. However, considerable testing of this method at various locations is required before complete reliance can be placed on this method. Another and more direct approach has been to couple an anemometer to the controls of a venting operation so that when the wind direction is unfavorable, the release of gases is automatically halted. It is evident that many nuclear processes are not amenable to this type of control.

In addition to the engineering applications, meteorology has significance to a practice largely confined to the atomic energy industry, that is, the routine monitoring of airborne radioactivity. Using meteorological data, monitoring stations may be sited in the prevailing wind directions and at locations where the highest concentrations are likely to occur. If this is not practical, it is possible to combine monitoring and meteorological data and to arrive at accurate concentrations for locations where measurements were not obtained. Since fixed monitoring stations may not provide all the coverage desired, it is often a practice to have mobile units that can monitor specific releases. If the practice is to be of maximum value, these mobile units should be vectored into position on the basis of current and expected meteorological conditions.

It is also necessary to mention the role that meteorology can play should a nuclear reactor accident result in the release of fission products to the air. Higher powered reactors operating for long times contain enough fission products to seriously overload the dilution capacity of the air. For example the external gamma dosage alone from high power reactor debris clouds can be dangerous miles from the point of release. Fig. 5 illustrates the external gamma dosages along the centerline of cloud travel computed using Holland's technique.[1] These computations assume a) long reactor lifetime, b) 100% instantaneous release of the contained fission products c) release at ground level in stable conditions with a 4 mph wind. Meteorology would enter into an accident of this magnitude in formulating disaster warning plans and by delineating areas and dosages covered by the cloud for various meteorological conditions. If at the time of such an accident it appears that radiological hazards may exist many miles from the site, it is mandatory that immediate information on current wind direction and speed be available to plan warnings and evacuation. Also, forecasts must be made to determine if wind shifts are likely or if precipitation may occur and cause a large fraction of the cloud material to deposit on the ground thus greatly increasing local disage and prolonging the effects of the incident.

It is evident that proper meteorological assistance and guidance can be of value to the site selection, engineering design, and actual operation of atomic energy plants.

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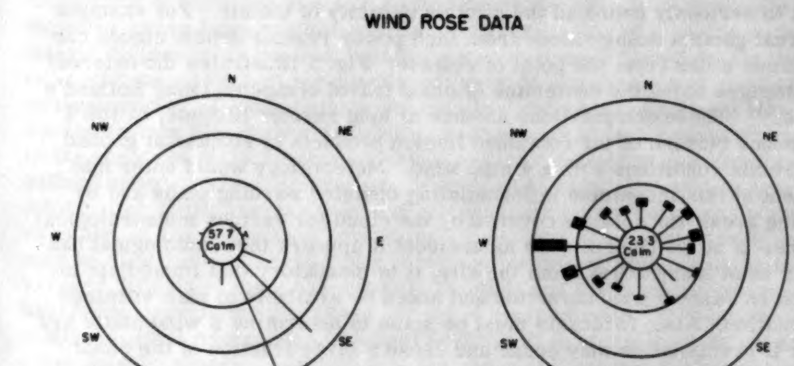


Fig. 1 Wind distributions at one station under inversion and lapse atmospheric conditions and during precipitation periods

SEASONAL VARIATIONS IN THE AVERAGE THERMAL GRADIENT BETWEEN 5 AND 400-FT. LEVELS
Temperature Sounding Data for the Year Sept. 1950 thru Aug. 1951 Central Facilities (WBO)

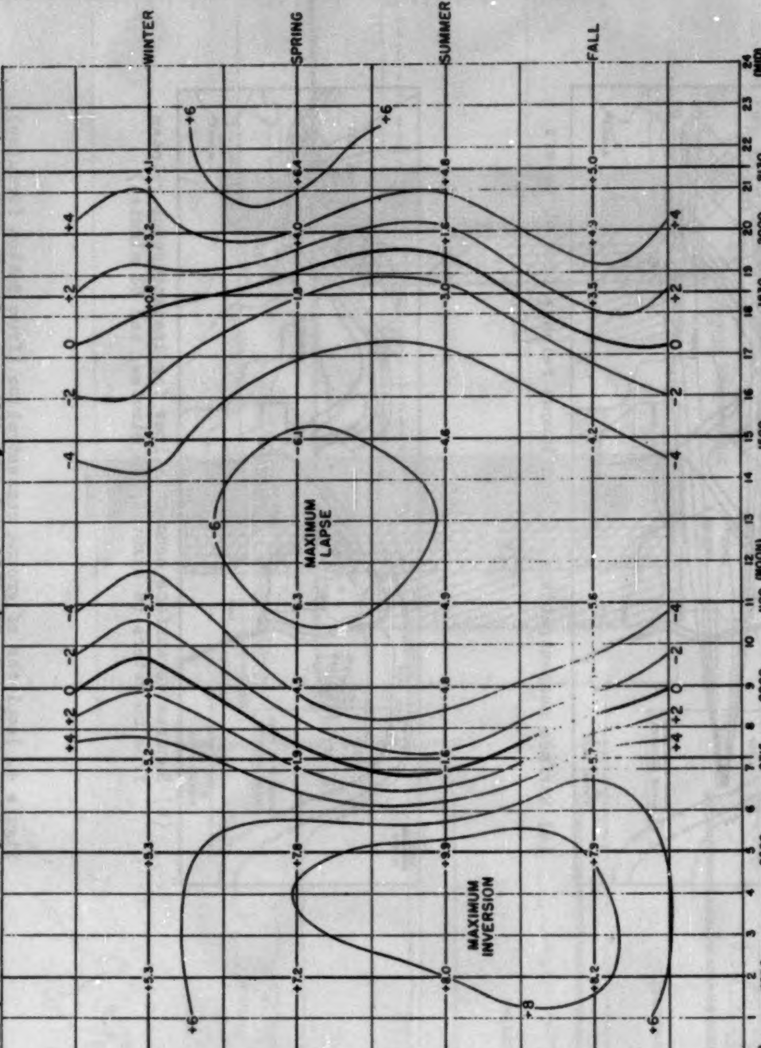
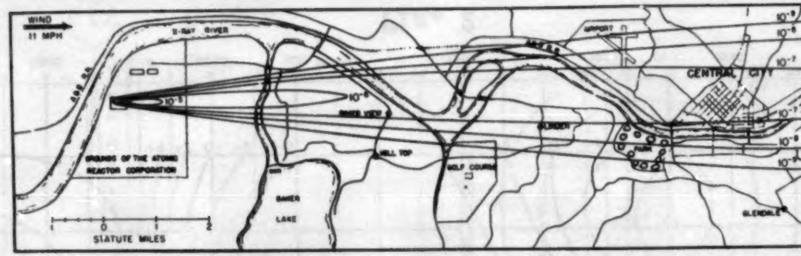
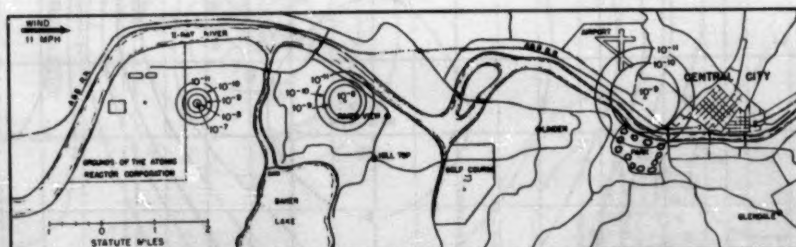


Fig. 2



(a) Surface concentrations for continuous release from 50 meters



(b) Successive surface concentrations for instantaneous release from 50 meters (8 minutes, 23 minutes, and 53 minutes)

Figure 4. Isopleths of ground concentration (from Sutton formulae).

Fig. 3

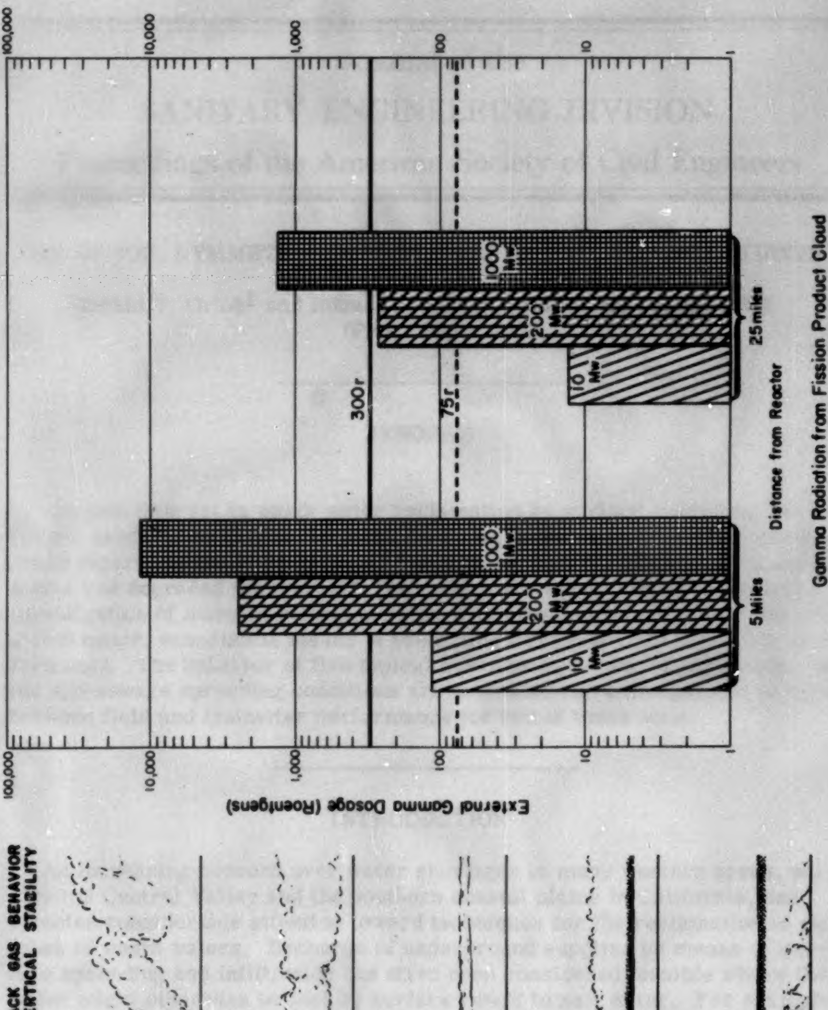

100,000
10,000
1,000
100
10
1
300r
75r
10 Mw
200 Mw
1000 Mw
5 Miles
25 miles
Distance from Reactor
External Gamma Dosage (Roentgens)
Gamma Radiation from Fission Product Cloud

Fig. 5

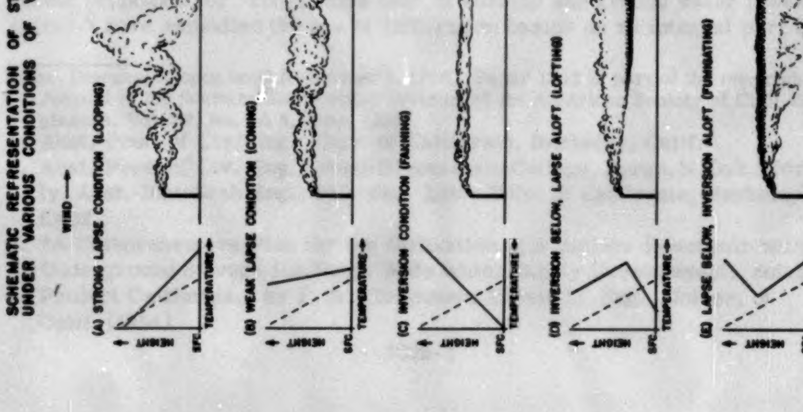

SCHEMATIC REPRESENTATION OF STACK GAS BEHAVIOR UNDER VARIOUS CONDITIONS OF VERTICAL STABILITY
WIND
(A) STRONG LAPSE CONDITION (LOOPING)
(B) WEAK LAPSE CONDITION (CONING)
(C) INVERSION CONDITION (FANNING)
(D) INVERSION BELOW, LAPSE ALOFT (LOFTING)
(E) LAPSE BELOW, INVERSION ALOFT (FUMIGATING)
HEIGHT
SFC.
TEMPERATURE

Fig. 4

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

USE OF SOIL LYSIMETERS IN WASTE WATER RECLAMATION STUDIES

Gerald T. Orlob[1] and Robert G. Butler,[2] Junior Members, ASCE
(Proc. Paper 1002)

SYNOPSIS

Current interest in waste water reclamation by surface spreading has dictated a need for further study of the mechanism of infiltration, the phenomena which determine the rates of water percolation, and the interaction of porous media and degraded waters. Soil lysimeters are found to be well suited to investigation of many important aspects of the reclamation problem and offer a convenient, economical means of predicting full scale field spreading performance. The behavior of five typical pervious agricultural soils under water and sewage spreading conditions are evaluated and a comparison is made between field and lysimeter performance for two of these soils.

INTRODUCTION

An increasing concern over water shortages in many western areas, notably the Central Valley and the southern coastal plains in California, has directed considerable attention toward techniques for the reclamation of all types of waste waters. Recharge of underground supplies by means of surface spreading and infiltration has often been considered feasible where the water might otherwise be lost by surface runoff to salt water. For example, recent proposals for "conjunctive use" of surface and ground water reservoirs[3,4] have embodied the use of infiltration basins as an integral part of

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3. "A Comprehensive Plan for the Utilization of a Surface Reservoir with Underground Storage for Basin Wide Water Supply Development: Solano Project California," by F. B. Clendenen, Thesis D. Eng., Univer. of Calif. (1954).

the reclamation scheme. Waste irrigation water has been introduced into ground water storage by means of surface spreading[5,6] and a number of experiments, some of these on full scale, have been concerned with the reclamation of domestic sewage by this procedure.[7,8]

One of the most complete field studies of sewage spreading, was that conducted over a period of 28 months (1950 - 1952) near Lodi, California.[9] In contrast to many prior experiments with sewage reclamation by spreading, this investigation incorporated extensive physical, chemical, and bacteriological analyses in attempting to determine some of fundamental phenomena which bear on the problem. While only a single soil, Hanford fine sandy loam, was studied, the experiments revealed that the rate of infiltration was dependent on the nature of surface treatment, the duration of application, the period of resting between applications, and the quality of the effluent applied. It was also concluded that a bacteriological safe water could be produced from a primary settled sewage after percolation through only four feet of Hanford soil. Infiltration rates were generally less than 0.3 cubic feet per square foot per day (feet per day) except during a short period immediately following the onset of spreading. When the basin was drained, dried, spaded and rested for several weeks infiltration rates, upon resumption of spreading, were substantially improved.

Excellent information has been obtained by Schiff[10,11] and Bliss, Johnson and Schiff[12] for water spreading on two agricultural soils, Hesperia and Exeter loams near Bakersfield, California. Using waste irrigation waters, these investigators reported sustained infiltration rates ranging from 1 to 3 feet per day. Special soil preparation, notably the use of soil additives such as cotton gin trash and the growth of forage crops, were found to be beneficial to infiltration. Pond arrangement and construction were also noted to influence performance.

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Objectives of Investigation

It is apparent that detailed studies such as those described can provide much in the way of a fundamental understanding of soil-waste water relationships; but due to the extreme diversity in soil and waste water characteristics it may be difficult to extend information obtained in such experiments to new situations. It is also obvious that such investigations are costly and not easily justifiable as a component of modest engineering studies. Consequently, a less costly method is needed for generalizing the findings of such studies and to provide data upon which to base engineering decisions on design of spreading installations.

In planning the studies which are reported, in part, in this paper it was postulated that the behavior of Hanford loam under field conditions at Lodi and Hespina loam under water spreading conditions at Bakersfield might be correlated with the performance of the same materials in pilot scale lysimeters. If a dependable correlation could be obtained it might then be possible, to use these relationships to predict, with a reasonable degree of accuracy, the behavior of other soils under field spreading conditions. The cost of lysimeter construction and operation, nominal in contrast to field test installations, would not be so burdensome as to prevent consideration of the widest choice of possible solutions for a reclamation problem.

While the entire investigation included detailed consideration of physical, chemical, and bacteriological factors as they might influence the feasability of spreading practices the present report is concerned only with the effect of physical phenomena on the rates of infiltration. Other facets of the reclamation problem, particularly the fate of bacteria during movement through porous media in underground waters, are still being studied and will be presented at a later date.

Investigation

Installation

Twenty lysimeters, each 5 feet deep and 3 feet in diameter, constructed from galvanized corrugated iron pipe sections welded to a steel base plate, were utilized for holding the soils under investigation. Graded gravel underdrains and collection manifolds were provided for each unit, the percolant being collected in a reservoir where accumulated discharge could be determined by hook gage observations. The discharge pipe from the collection manifold was constructed in such a way that the point of discharge was at the same elevation as the gravel-soil interface in the lysimeter, thus producing a "perched aquifer" and a plane of atmospheric pressure at the bottom of the soil column.

Specially constructed devices designed to measure tension (or pressure) in the liquid phase of partially saturated soil columns were installed in five of the lysimeters. These tensiometers consisted simply of a 3mm I.D. glass manometer leg attached by means of a flexible tube to a porous filter cylinder tip. Various types of tips were investigated, including glass tubing packed with glass wool or plaster of Paris, but a 10 x 55 mm, porosity No. 2 filter cylinder manufactured by the Coors Porcelain Co. was found to be the most satisfactory for the range of tensions encountered during the investigation.

In order to make the soil as near homogeneous as possible large extraneous particles and debris were removed by screening through a 1/8 inch mesh wire screen prior to placing. The soil was placed in the lysimeter unit in a random manner without artificial compaction. Each soil was allowed to consolidate under its own weight. During the course of placing the soils in the lysimeters samples were taken and composited for use in obtaining physical and chemical analyses.

The construction details of a typical lysimeter are shown in Figure 1.

Fresh Water and Sewage Supply

Fresh water used in the studies was obtained from the distribution system of the East Bay Municipal Utility District. Its chemical characteristics are shown in Table I.

TABLE I

Chemical Characteristics of Fresh Water

Used in Spreading Studies

Constituent	Concentration - ppm	
	Average	Range
Hardness ($CaCO_3$)	57.6	23.6 - 93.2
Turbidity	1	
pH	8.9	8.3 - 9.7
Monovalent - Total Cation Ratio	0.164	0.08 - 0.29

Sewage used in the investigations was pumped directly from a trunk sewer which serves a typical residential-commercial area of Richmond California. No significant amount of industrial waste was present. Primary treatment was provided by settling and skimming in a 7000-gallon circular clarifier with a theoretical detention time of two hours and a surface loading of 900 gallons per square foot per day. Supplementary treatment was provided as needed by additional sedimentation or mechanical filtration. Typical composition of the settled sewage utilized is given in Table II.

Both sewage and water were applied to the lysimeters through a manifold system connected directly to the source of supply and the rate of application was regulated by adjustable float valves and by overflow pipes.

Soil Characteristics

The soils used in the investigation were selected as typically representative of California agricultural soils from areas where the spreading of water or sewage may offer a potential solution to water shortages. Of the five types chosen, three—Columbia, Hesperia, and Yolo—are classified as sandy loams. Hanford soil, the same medium studied at Lodi, is defined as a fine sandy

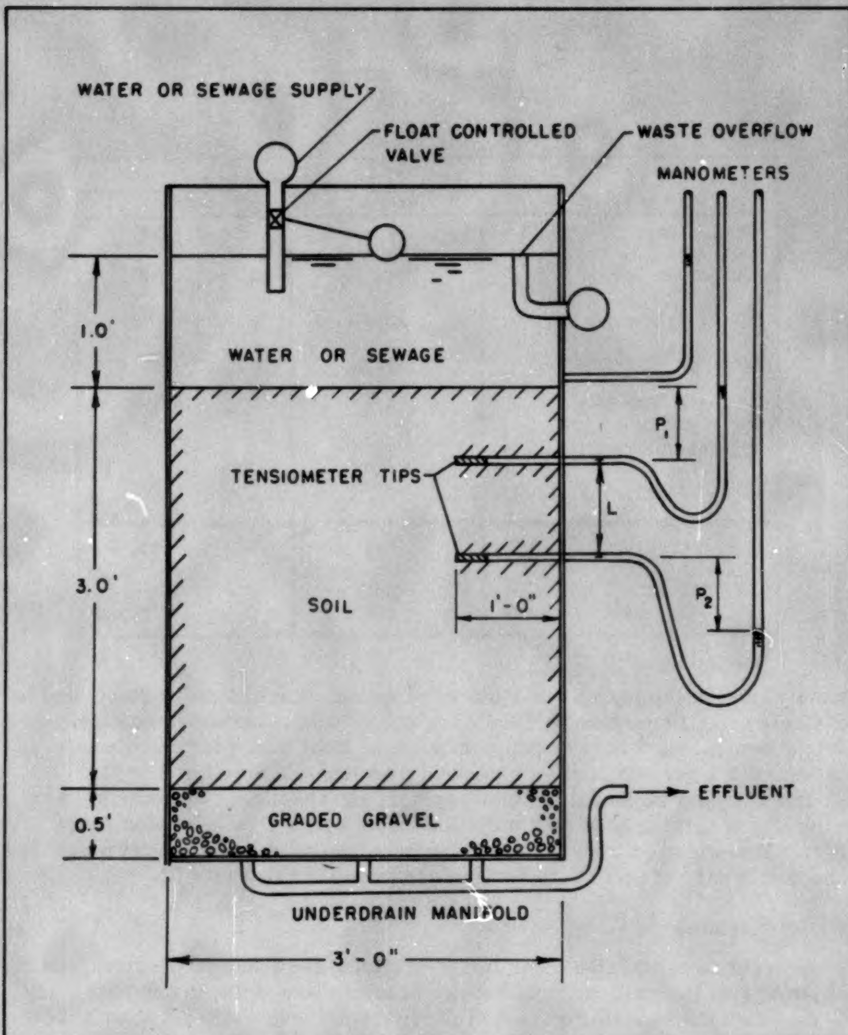

FIG. 1 CONSTRUCTION DETAILS OF TYPICAL SOIL LYSIMETER

TABLE II

Composition of Settled Sewage Applied To

Soils in Lysimeters

Constituent	Concentration - ppm	
	Average	Range
BOD, 5-day, 20°C	187	90 - 322
Suspended Solids	135	44 - 324
Total Nitrogen	40.8	32.7 - 55.9
Ammonia Nitrogen	31.3	17.2 - 50.4
Organic Nitrogen	9.0	4.3 - 18.4
Nitrate Nitrogen	0.5	0 - 1.8
Total Alkalinity ($CaCO_3$)	209	120 - 300
pH	7.4	7.1 - 7.9
Monovalent - Total Cation Ratio	0.641	0.523 - 0.760

loam while the Oakley soil is considered a sand. Each of the soils studied is of fairly wide occurrance in California and is usually associated with permeable subsoils and deep permeable substrata. None contained soluble salts in excess of 0.1 per cent and all exhibited a neutral reaction (pH 6 to 8).

The extreme variability in both physical and chemical characteristics of naturally occurring soils is amply illustrated by the five materials considered in this investigation. Particle grading and size distribution is shown in Fig. 2 and a summary of soil characteristics is presented in Table III.

Water Spreading

In order to establish a basis for determining the effect of the constituents of sewage on the infiltration of sewage effluents into soils, it was necessary to establish the behavior of each of the five soils under spreading with fresh water and to consider the factors which control infiltration rates.

Christiansen and Magistrad,[13] in investigations of infiltration of water into undisturbed soil plots and into core samples, observed the frequent recurrence of a characteristic time-rate curve which they noted to be comprised of three distinct phases. Infiltration rates on samples investigated by these

13. "Report for 1944 - Laboratory Phase of Cooperative Water Spreading Study," by Christiansen, J. E. and Magistrad, O. C., U. S. Reg. Salinity Lab. (unpublished).

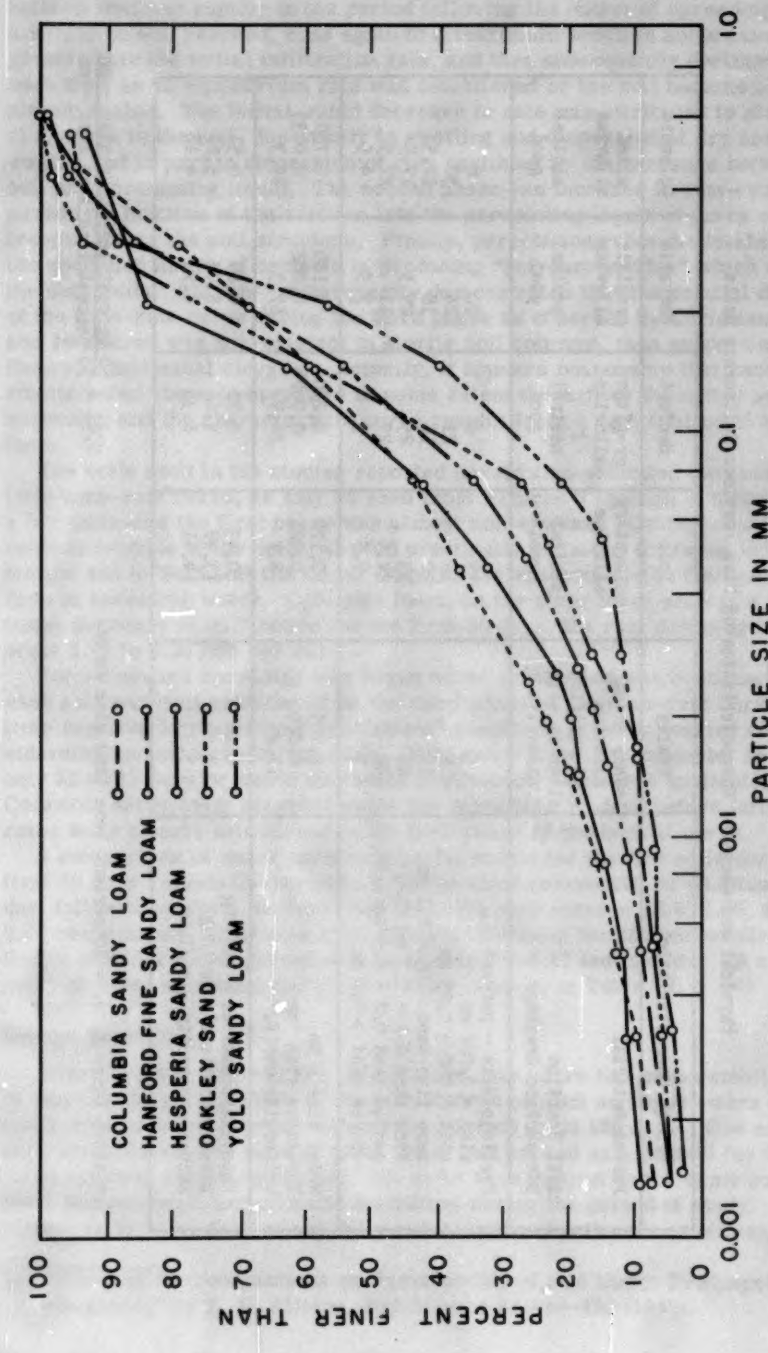

FIG. 2 SOIL PARTICLE SIZE DISTRIBUTION

TABLE III

Physical and Chemical Characteristics of Five Pervious California Soils

Soil Characteristic	Oakley	Yolo	Hanford	Hesperia	Columbia
Parent Material	sandy mixed alluvium wind modified	sedimentary alluvium	granitic alluvium	granitic alluvium	mixed alluvium
Soil Reaction	slightly acid	neutral	neutral	neutral	neutral
Sub-surface drainage	excessive	good	good	good	good
Particle Size - percent					
clay < 0.002 mm	5	3	6	10	8
silt 0.002 - 0.05 mm	9	19	21	24	30
very fine sand 0.05 - 0.1 mm	15	20	16	18	12.5
fine sand 0.1 - 0.2 mm	26	33	25	29.5	17.5
medium sand 0.2 - 0.5 mm	42	24.5	29	11	27.5
coarse sand > 0.5 mm	3	0.5	3	7.5	4.5
Modal size - mm	0.205	0.170	0.210	0.180	0.180
Effective size *mm	0.020	0.021	0.0074	0.002	0.0033
Uniformity coeff.*	11.2	8.1	24.9	67.3	47.3
Monovalent cations - me/100g	0.24	0.43	0.72	0.89	0.51
Divalent cations - me/100g	2.79	13.98	5.66	8.02	5.67
Exchange capacity - me/100g	3.03	14.41	6.38	8.91	6.18

* After Hazen E. S. = 10 percent less than size in mm.

$$U.C. = \frac{60 \text{ percent less than size - mm}}{10 \text{ percent less than size - mm}}$$

authors declined rapidly in the period following the outset of spreading, until a minimum was reached, rose again to a maximum which in some cases was greater than the initial infiltration rate, and then subsequently declined until such time as an equilibrium rate was established or the soil became completely sealed. The initial rapid decrease in rate was attributed to structural changes in the soil, due in part to swelling and dispersion of dry soil upon wetting and in part to dispersion of clay particles by ion exchange between soil and percolating liquid. The second phase—an increase in rate—was apparently a function of the solution into the percolating liquid of gases entrapped within the soil structure. Finally, percolation rates diminished under the continued action of bacteria in producing "polysaccharides" which clogged the soil voids. Allison[14] subsequently demonstrated that the gradual decline of the time-rate curve during the third phase as observed by Christiansen and Magistrad was non-existant in sterile soil columns, thus supporting their theory of microbial clogging. Actually, it appears reasonable that each of the effects noted above is operative to some extent throughout the entire period of spreading and the characteristic curve results from a combination of all effects.

The soils used in the studies reported herein also exhibited the characteristic time-rate curve, as may be seen from Figures 3 through 7, although in a few instances the first phase was almost non-existant. Oakley sand, the most permeable of the soils, showed practically no initial decrease in infiltration and in Yolo soil the initial drop in rate was confined to the first few days of spreading water. Columbia loam, on the other hand, showed a continual decrease in infiltration for the first 30 days, the rate dropping from about 1.75 to 0.30 feet per day.

Before sewage spreading was begun water application was continued until each soil was well established on the third phase of the time-rate curve. The time required to reach the "equilibrium" condition, however, varied considerably among the different soils. Yolo sandy loam, for example, required only 12 to 15 days or water spreading preliminary to sewage application while Columbia sandy loam received water for more than 70 days before infiltration rates were clearly established in the final phase of the typical curve.

A comparison of water spreading performance for the five soils during the first 30 days reveals Oakley sand to be the most permeable, at 40.3 feet per day, followed by Yolo, Hanford, and Hesperia with rates of 12.9, 2.53, and 2.37 respectively. Columbia soil, which incidentally had the widest distribution of particle sizes, passed only an average of 0.57 feet per day. A summary of water spreading for the five soils is given in Table IV.

Sewage Spreading

After the third phase of the typical time-rate curve had been established in each of the soils, fifteen of the units—three of each soil type—were inundated with primary sewage effluent for periods up to 150 days. One unit of each soil continued to receive fresh water and served as a control for the three columns receiving sewage. All units were subject to the same surface head, temperature, and climatic conditions during the period of study. Infiltration rates were determined daily and samples of influent and effluent were

14. "Effect of Microorganisms on Permeability of Soil Under Prolonged Submergence," by L. E. Allison, Soil Science 63:439-450 (1947).

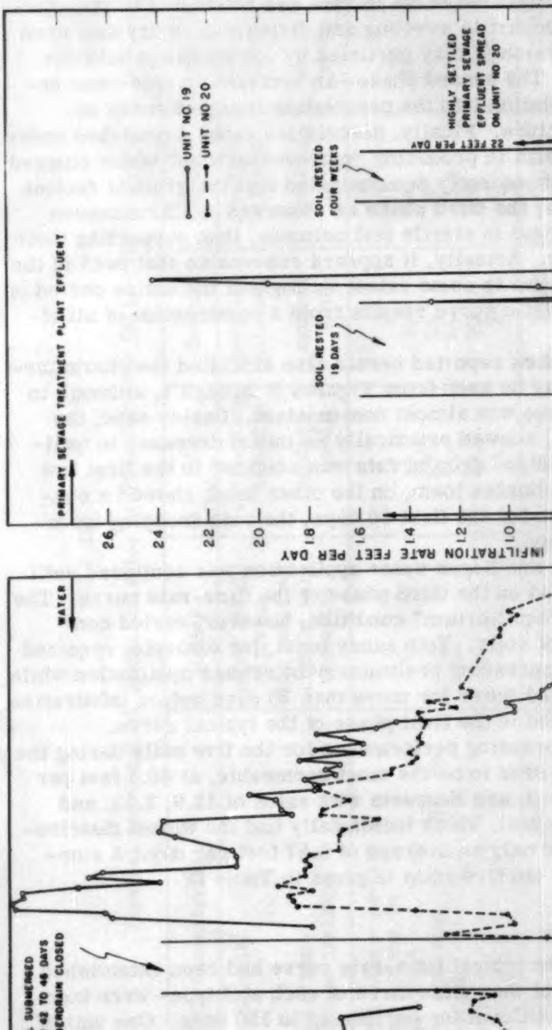

FIG. 3 RATES OF INFILTRATION OF WATER AND SEWAGE INTO OAKLEY SAND

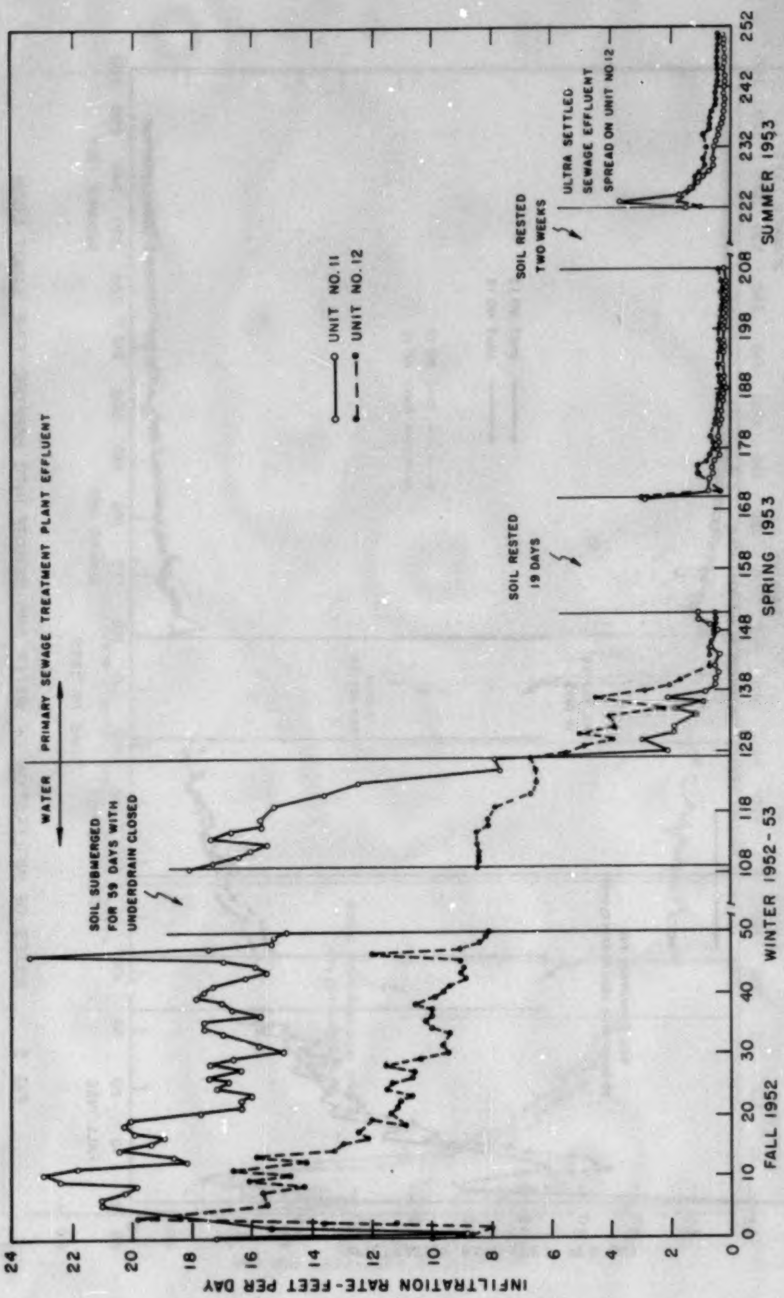

FIG. 4 RATES OF INFILTRATION OF WATER AND SEWAGE INTO YOLO SANDY LOAM

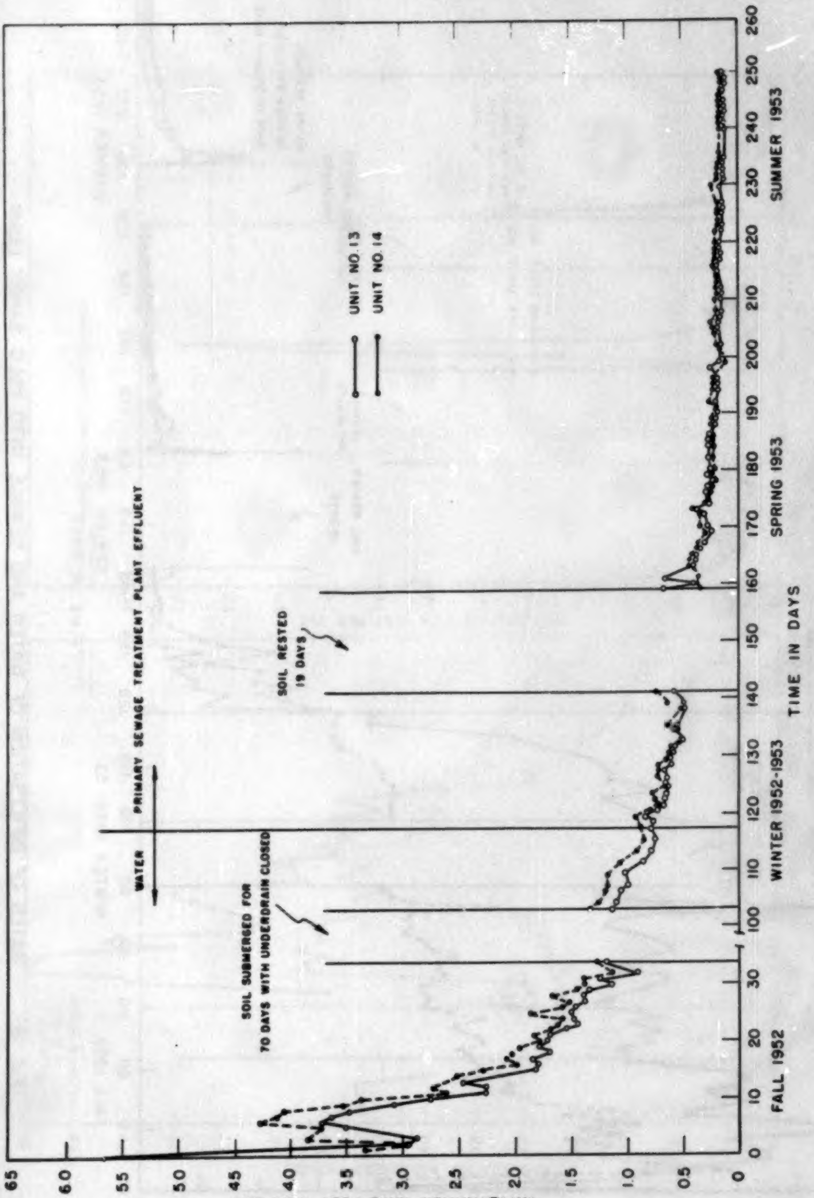

FIG. 5 RATES OF INFILTRATION OF WATER AND SEWAGE INTO HANFORD FINE SANDY LOAM

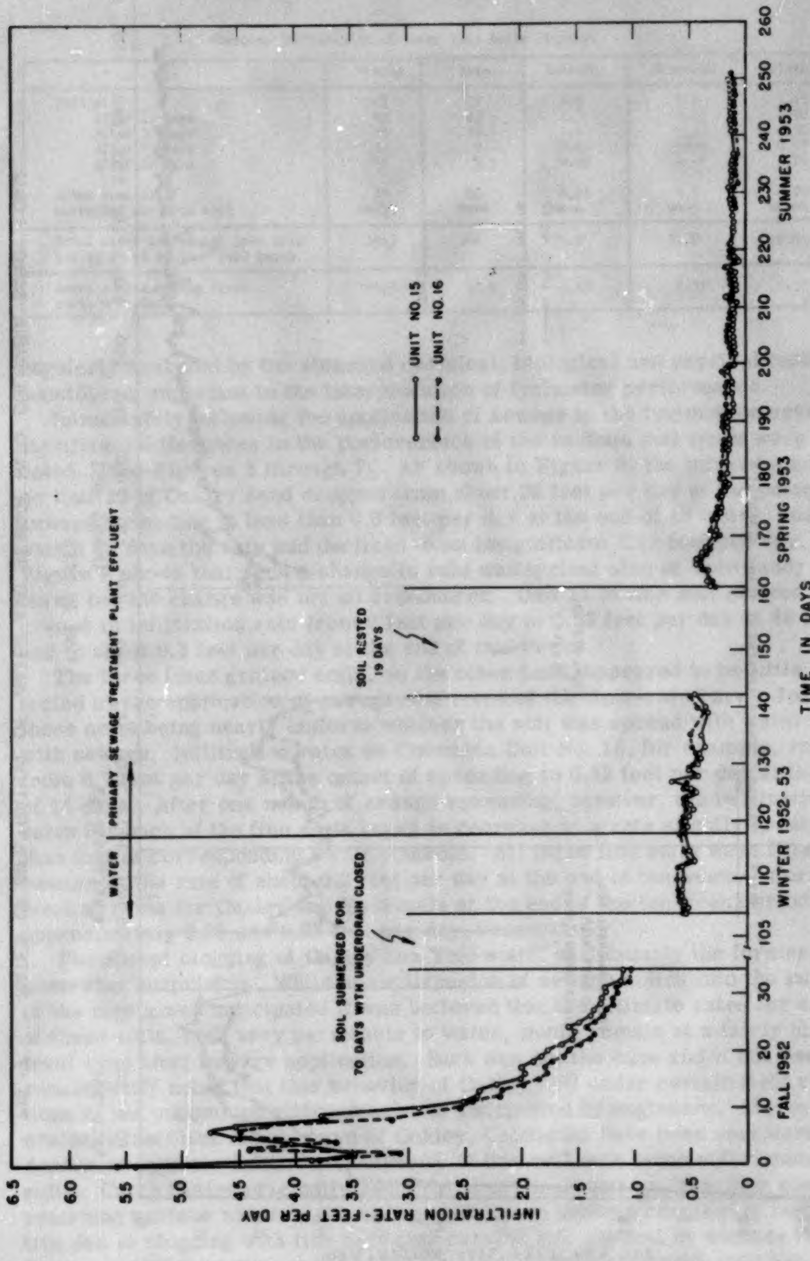

FIG. 6 RATES OF INFILTRATION OF WATER AND SEWAGE INTO HESPERIA SANDY LOAM

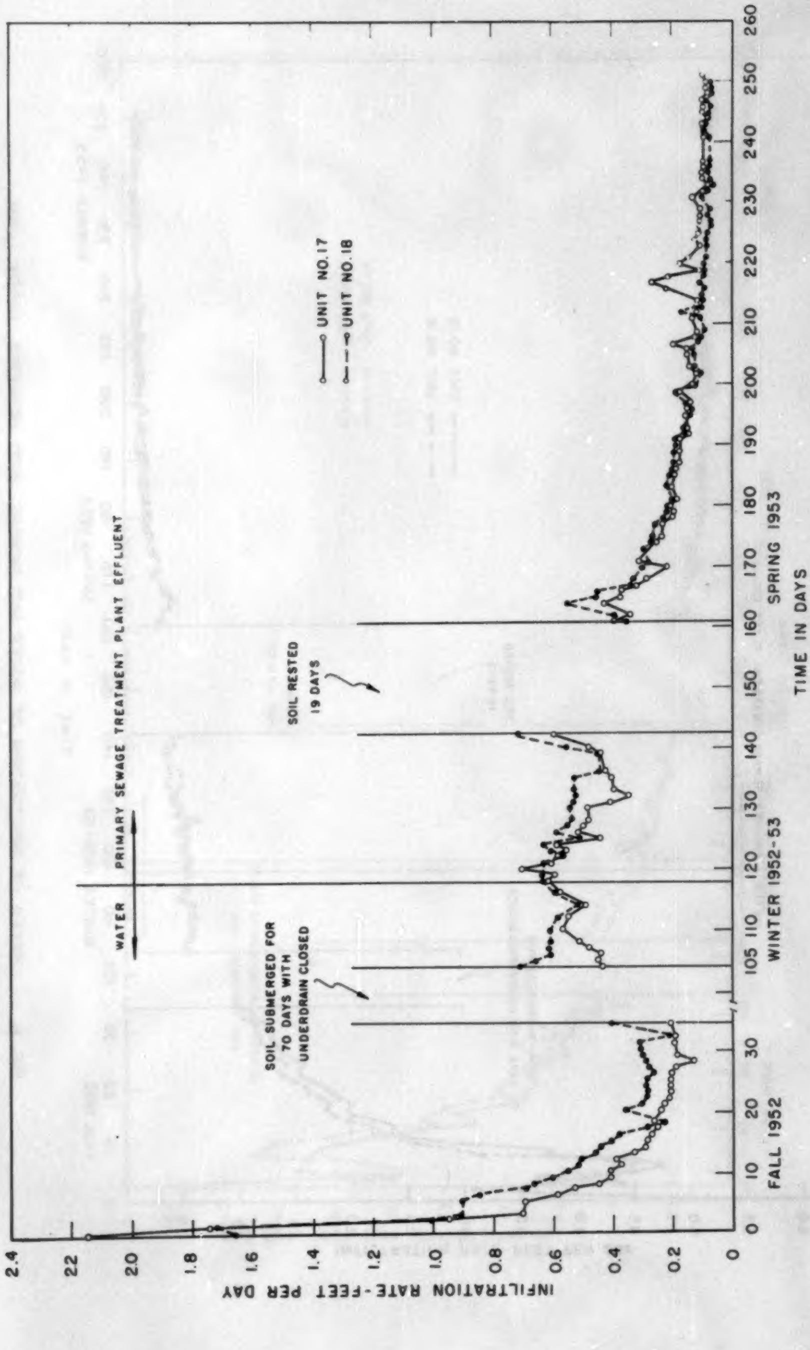

FIG. 7 RATES OF INFILTRATION OF WATER AND SEWAGE INTO COLUMBIA SANDY LOAM

TABLE IV

Observed Infiltration of Water Into Soils (ft/day)

	Oakley	Yolo	Hanford	Hesperia	Columbia
Initial	29	10	6.4	5.2	1.75
After 15 days	47	13	2.3	1.85	0.40
After 30 days	43	10.5	1.4	1.15	0.30
After 45 days	34	9	0.85	—	0.50
After 60 days	26	7.5	0.60	—	0.74
After removal of entrapped air from soil	47 @t=15	20 @t=4	4.25 @t=6	4.5 @t=5	0.70 @5=50
Total water introduced into soil during first month - feet depth	1213	386	75.9	71.0	17.0
Average rate during first month - ft/day	40.3	12.9	2.53	2.37	0.57

regularly analyzed by the standard chemical, biological and physical tests considered important to the interpretation of lysimeter performance.

Immediately following the application of sewage to the lysimeters several significant differences in the performance of the various soil types were noted. (See Figures 3 through 7). As shown in Figure 8, the infiltration rate on Unit 20 of Oakley sand dropped from about 26 feet per day at the outset of sewage spreading to less than 0.6 feet per day at the end of 48 hours, and within 15 days the rate had declined to an insignificant 0.12 feet per day. Figure 9 shows that such a change in rate was typical also of Yolo sandy loam, but the change was not so pronounced. Unit 11 of this soil showed a decrease in infiltration rate from 9 feet per day to 0.72 feet per day in 48 hours, and to about 0.3 feet per day at the end of two weeks.

The three finer grained soils, on the other hand, appeared to be little affected by the application of sewage, the trend of the time-rate curves for these soils being nearly uniform whether the soil was spread with water or with sewage. Infiltration rates on Columbia Unit No. 18, for example, ranged from 0.7 feet per day at the outset of spreading to 0.52 feet per day at the end of 14 days. After one month of sewage spreading, however, the infiltration rates for each of the fine soils began to decrease at a rate slightly greater than that of corresponding water controls. All three fine soils were filtering sewage at the rate of about 0.2 feet per day at the end of ten weeks. Corresponding rates for Oakley and Yolo soils at the end of the ten week period were approximately 0.08 and 0.25 feet per day, respectively.

The abrupt clogging of Oakley and Yolo soils, particularly the former, was somewhat surprising. While some intrusion of sewage solids into the surface of the media was anticipated it was believed that the ultimate rates for each of these soils, both very permeable to water, would remain at a fairly high level even after sewage application. Such was not the case and it has been subsequently noted that this behavior of Oakley soil under certain field conditions is not uncommon although seldom anticipated by engineers. Storm drainage facilities for the town of Oakley, California have been considerably dependent upon the infiltration capacity of this soil with some unfortunate results. Catch basins originally designed to act as sumps or "leaching pits" returning surface water to the underground soon become completely ineffective due to clogging with fine particles carried into the soil by surface runoff. Recent experimentation at the town's water filtration plant with infiltration

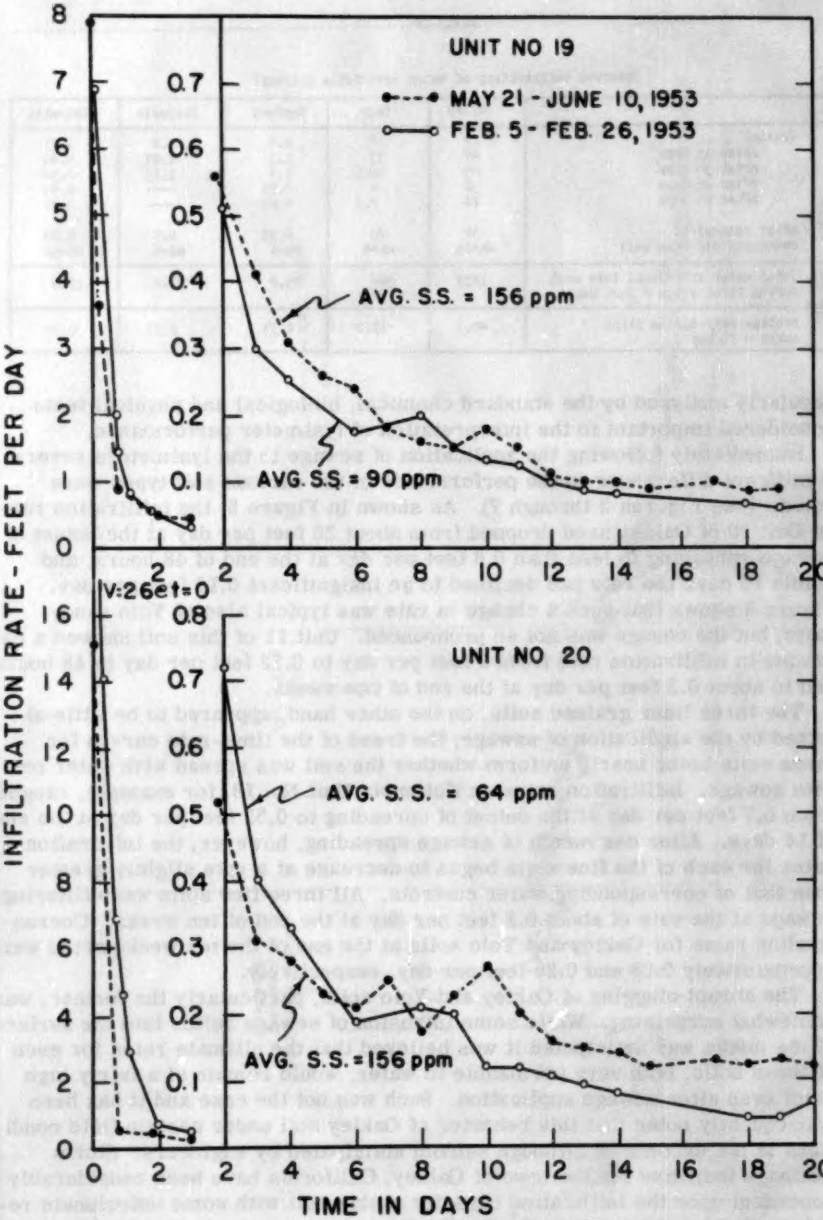

FIG. 8 EFFECT OF SOIL CLOGGING ON INFILTRATION RATE - OAKLEY SAND

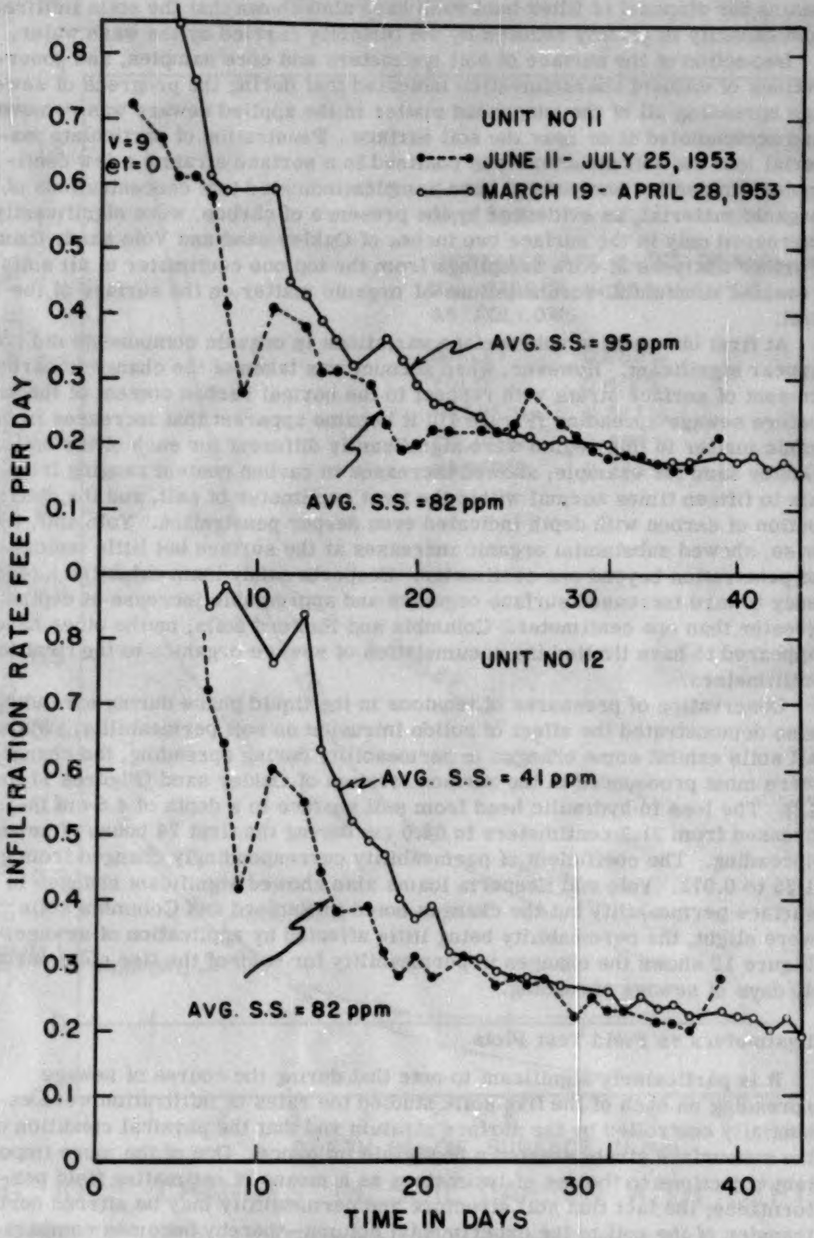

FIG. 9 EFFECT OF SOIL CLOGGING ON INFILTRATION RATE - YOLO SANDY LOAM

basins for disposal of filter backwash have also shown that the soils infiltration capacity is greatly reduced by the turbidity carried by the wash water.

Inspection of the surface of soil lysimeters and core samples, and observations of effluent characteristics indicated that during the progress of sewage spreading all of the suspended matter in the applied sewage was removed and accumulated at or near the soil surface. Penetration of particulate material into the soil structure was confined to a surface stratum a few centimeters in depth. Analyses of core samples indicated that concentrations of organic material, as evidenced by the presence of carbon, were significantly increased only in the surface two inches of Oakley sand and Yolo sandy loam. Further analyses of core samplings from the top one centimeter of all soils revealed substantial accumulations of organic matter on the surface of the soil.

At first observation sub-surface variations in organic components did not appear significant. However, when account was taken of the change in carbon content of surface strata with respect to the normal carbon content of the soil before sewage spreading (Figure 10) it became apparent that increases in organic matter in this region were significantly different for each of the soils. Oakley sand for example, showed increases in carbon content ranging from six to fifteen times normal within the first centimeter of soil, and the distribution of carbon with depth indicated even deeper penetration. Yolo soil, likewise, showed substantial organic increases at the surface but little indication of penetration beyond one centimeter. Hesperia sandy loam exhibited a tendency toward increased surface organics and appreciable increase at depths greater than one centimeter. Columbia and Hanford soils, on the other hand, appeared to have limited the accumulation of sewage organics to the first four millimeters.

Observation of pressures of tensions in the liquid phase during spreading also demonstrated the effect of solids intrusion on soil permeability. While all soils exhibit some changes in permeability during spreading, the changes were most pronounced in the surface stratum of Oakley sand (Figures 11 and 12). The loss in hydraulic head from soil surface to a depth of 4.6 cm increased from 31.2 centimeters to 68.0 cm during the first 24 hours of sewage spreading. The coefficient of permeability correspondingly changed from 4.35 to 0.072. Yolo and Hesperia loams also showed significant changes in surface permeability but the changes noted in Hanford and Columbia soils were slight, the permeability being little affected by application of sewage. Figure 12 shows the changes in permeability for each of the five soils during 40 days of sewage spreading.

Lysimeters vs Field Test Plots

It is particularly significant to note that during the course of sewage spreading on each of the five soils studied the rates of infiltration were essentially controlled by the surface stratum and that the physical condition of the subsurface strate exerted a negligible influence. One of the more important objections to the use of lysimeters as a means of estimating field performance; the fact that soil structure and permeability may be altered during transfer of the soil to the experimental column—thereby becomes comparatively unimportant. The field practice of spading, harrowing, or otherwise conditioning the surface of spreading basins to improve infiltration capacities necessarily modifies soil structure and permeability. Lysimeter soils,

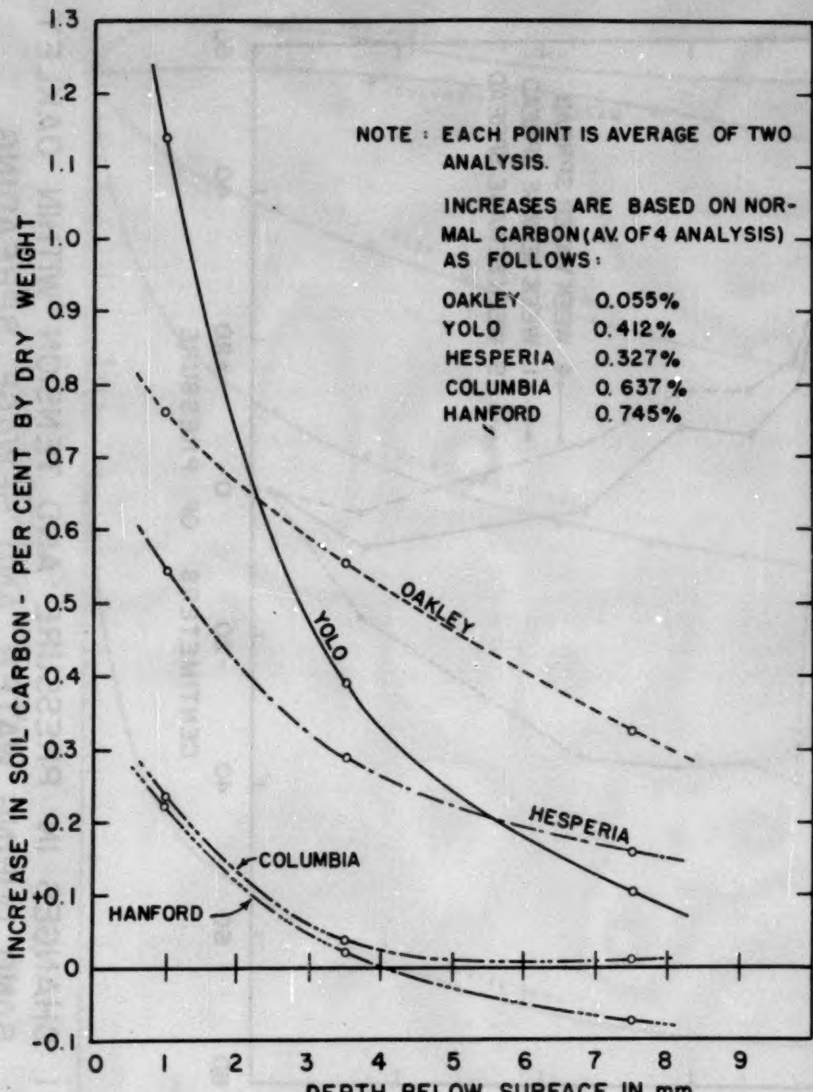

FIG. 10 CHANGES IN SOIL CARBON WITH DEPTH FOLLOWING SEWAGE SPREADING

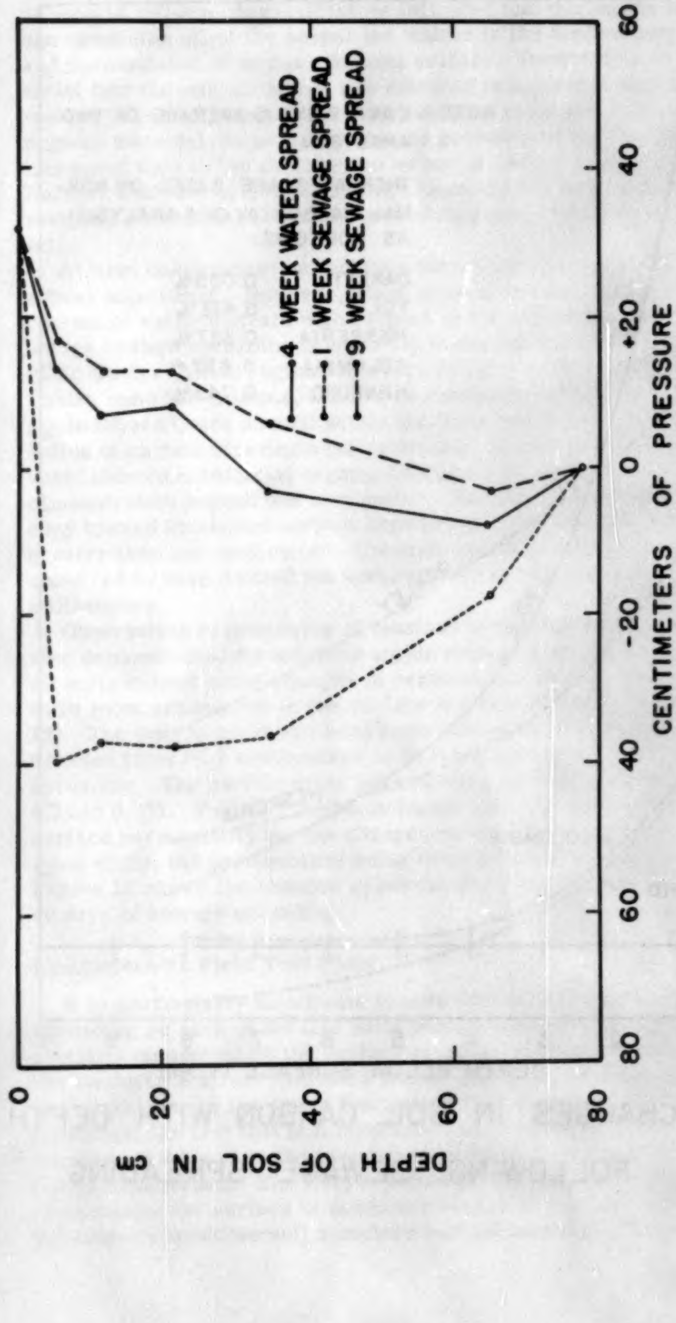

FIG. 11 CHANGES IN PRESSURE AND TENSION WITHIN OAKLEY SAND DURING WATER AND SEWAGE SPREADING

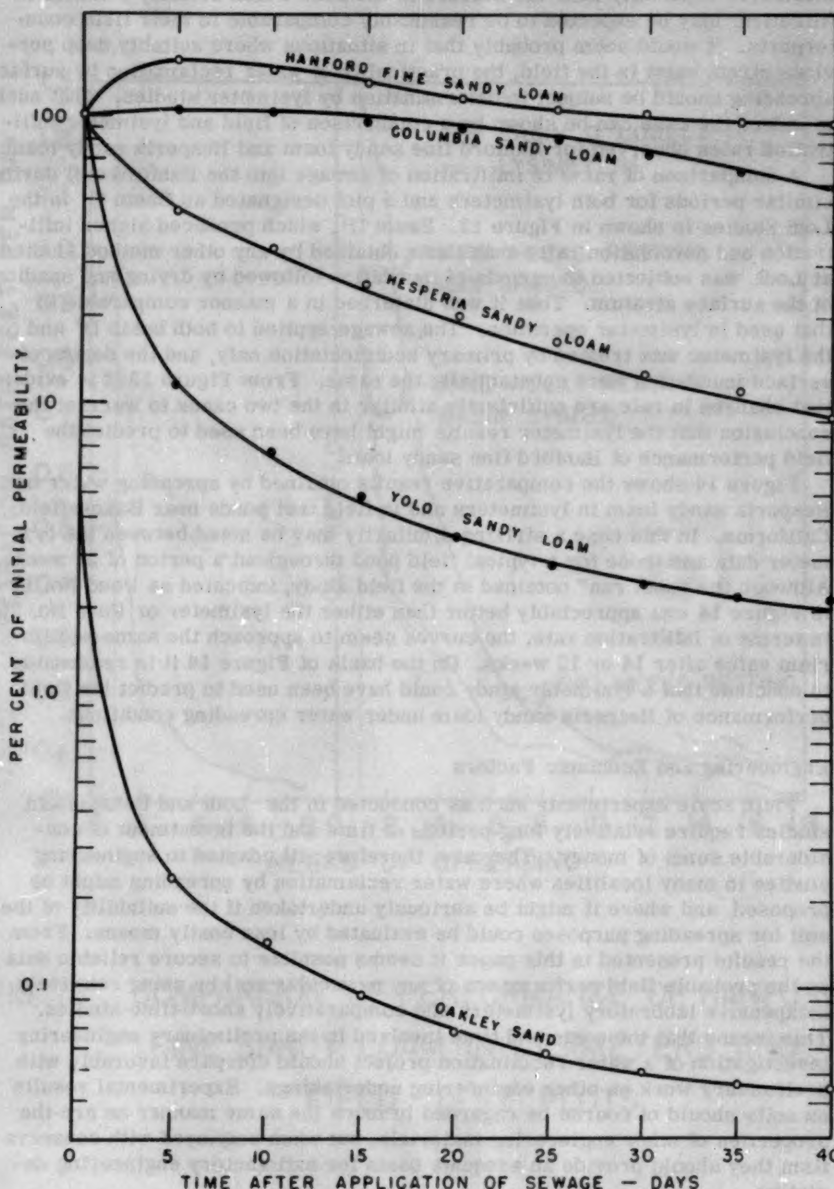

FIG. 12 CHANGES IN PERMEABILITY OF SURFACE STRATA DURING SEWAGE SPREADING

therefore, especially near the surface in the zone which actually controls infiltration, may be expected to be reasonably comparable to their field counterparts. It would seem probably that in situations where suitably deep pervious strata exist in the field, the practicality of water reclamation by surface spreading should be subject to determination by lysimeter studies. That such is indeed the case can be shown by a comparison of field and lysimeter infiltration rates observed for Hanford fine sandy loam and Hesperia sandy loam.

A comparison of rates of infiltration of sewage into the Hanford soil during similar periods for both lysimeters and a plot designated as Basin D' in the Lodi Studies is shown in Figure 13. Basin D', which produced higher infiltration and percolation rates than those obtained by any other method studied at Lodi, was subjected to periods of inundation followed by drying and spading of the surface stratum. Thus it was disturbed in a manner comparable to that used in lysimeter operation. The sewage applied to both basin D' and the lysimeter was treated by primary sedimentation only, and the depths of surface inundation were substantially the same. From Figure 13 it is evident that changes in rate are sufficiently similar in the two cases to warrant the conclusion that the lysimeter results might have been used to predict the field performance of Hanford fine sandy loam.

Figure 14 shows the comparative results obtained by spreading water on Hesperia sandy lcam in lysimeters and in field test ponds near Bakersfield, California. In this case a striking similarity may be noted between the lysimeter data and those for a typical field pond throughout a period of 20 weeks. Although the "best run" obtained in the field study, indicated as Pond No. 19 in Figure 14 was appreciably better than either the lysimeter or Pond No. 25 in terms of infiltration rate, the curves seem to approach the same equilibrium value after 14 or 15 weeks. On the basis of Figure 14 it is reasonable to conclude that a lysimeter study could have been used to predict the field performance of Hesperia sandy loam under water spreading conditions.

Engineering and Economic Factors

Field scale experiments such as conducted in the Lodi and Bakersfield studies require relatively long periods of time and the investment of considerable sums of money. They are, therefore, ill adapted to engineering studies in many localities where water reclamation by spreading might be proposed, and where it might be seriously undertaken if the suitability of the soil for spreading purposes could be evaluated by less costly means. From the results presented in this paper it seems possible to secure reliable data on the probable field performance of any particular soil by using relatively inexpensive laboratory lysimeters and comparatively short-time studies. This means that the costs and time involved in the preliminary engineering investigation of a water reclamation project should compare favorably with preliminary work on other engineering undertakings. Experimental results on soils should of course be regarded in much the same manner as are the properties of other engineering materials, but when employed with conservatism they should provide an adequate basis for satisfactory engineering decisions.

SUMMARY AND CONCLUSIONS

1) The infiltration capacities of five pervious California agricultural soils

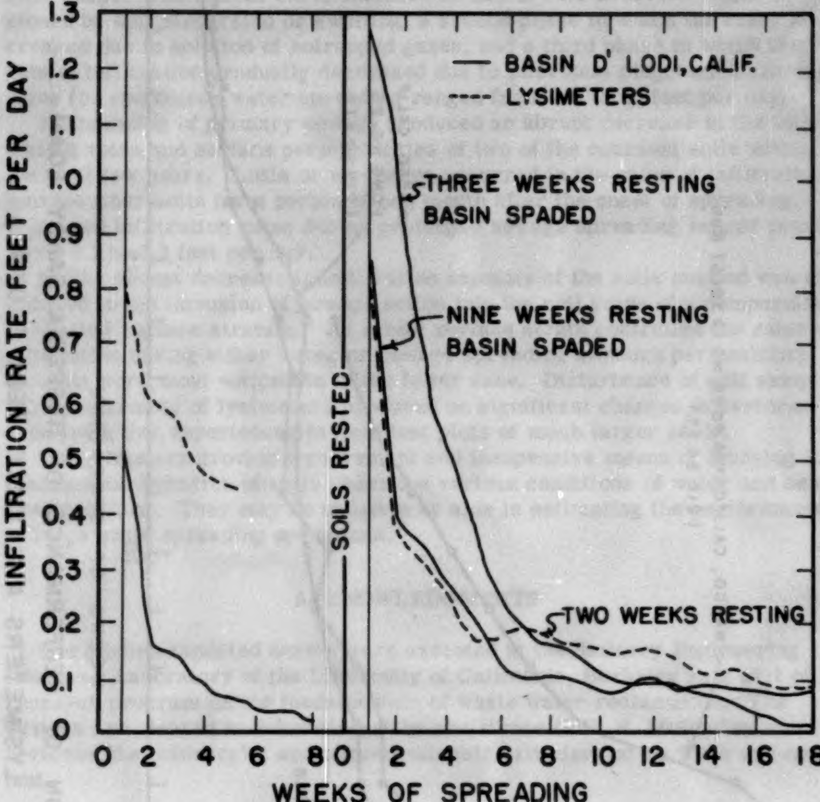

FIG. 13 COMPARISON OF PERFORMANCE OF HANFORD FINE SANDY LOAM IN LYSIMETERS AND FIELD TEST PLOTS

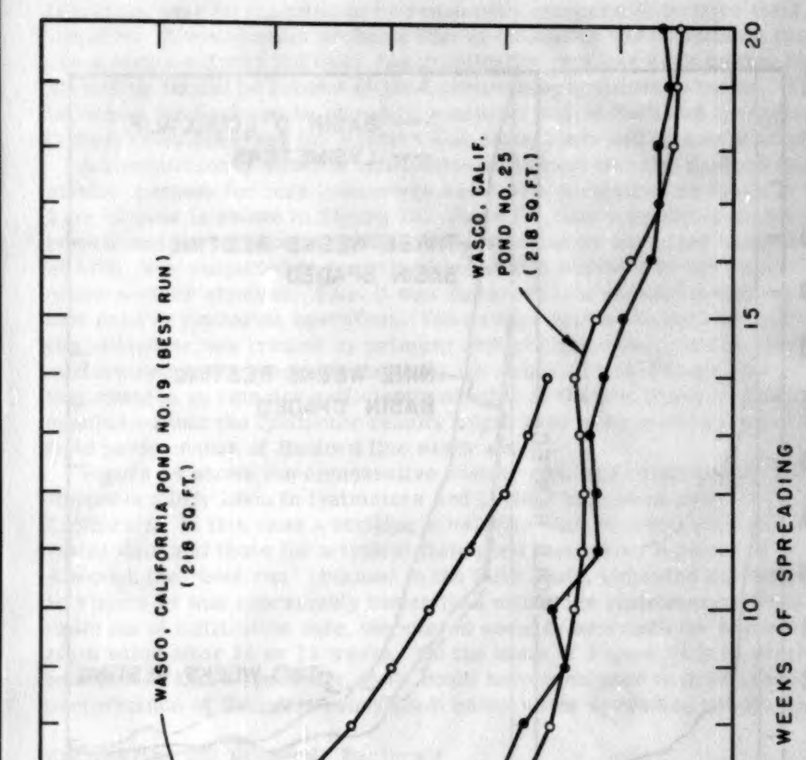

FIG. 14 COMPARISON OF PERFORMANCE OF HESPERIA SANDY LOAM IN LYSIMETERS AND FIELD TEST PLOTS

during prolonged spreading with water and primary sewage effluent were determined using soil lysimeters.

2) Each of the soils exhibited time-infiltration rate curves of a characteristic shape. The typical curve included an initial rate decrease phase occasioned by soil dispersion or swelling, a second phase in which the rates increased due to solution of entrapped gases, and a third phase in which the rate of infiltration gradually decreased due to microbial clogging. Infiltration rates for continuous water spreading ranged from 0.6 to 40 feet per day.

3) Spreading of primary sewage produced an abrupt decrease in the infiltration rates and surface permeabilities of two of the coarsest soils within the first few hours. Little or no change occurred in the rates of infiltration into the finer soils for a period of one month after the onset of spreading. Sustained infiltration rates during prolonged sewage spreading ranged from about 0.1 to 0.3 feet per day.

4) The abrupt decrease in infiltration capacity of the soils studied was attributed to the intrusion of sewage solids into the soil voids of a comparatively shallow surface stratum. As a rule surface strata controlled the rates of infiltration during either water or sewage spreading although permeability changes were most noticeable in the latter case. Disturbance of soil samples during assembly of lysimeters produced no significant changes in performance from that experienced in field test plots of much larger scale.

5) Lysimeters provide a convenient and inexpensive means of studying the fundamental behavior of soils under the various conditions of water and sewage spreading. They may be valuable as aids in estimating the performance of large scale spreading operations.

ACKNOWLEDGMENTS

The studies reported herein were executed at the Sanitary Engineering Research Laboratory of the University of California, Berkeley as a part of a research program on the fundamentals of waste water reclamation. The writers are pleased to acknowledge the assistance of P. H. McGauhey who reviewed the manuscript and offered valuable criticism on its form and content.

during prolonged spreading with water and secondary sewage effluent were de- termined using small lysimeters.

2) Each of the three infiltration rate-time relationships exhibited a characteristic shape. The typical curve indicated an initial rate decay [illegible] followed by [illegible], a second phase in which the rate [illegible] cumulative dissolution of entrapped gases, and a third phase in which the rate of infiltration gradually decreased due to biological clogging. Infiltration rates for [illegible] secondary sewage effluent ranged from [illegible] to [illegible] feet per day.

3) Intermittent [illegible] produced an average increase in the infiltration rate and resulted in [illegible] one or two of the [illegible] within the [illegible]. [illegible] occurred in the rates of infiltration [illegible] period of one month after the [illegible] [illegible] infiltration rates during secondary sewage [illegible] from about [illegible] feet per day.

4) The [illegible] decrease in infiltration capacity of the soils studied was attributed to the [illegible] of sewage solids into the soil [illegible] of a [illegible] surface [illegible]. As a rule surface [illegible] [illegible] the rates of infiltration during either water or sewage spreading [illegible] changes were most noticeable in the latter case. [illegible] during [illegible] of [illegible] produced no significant changes in infiltration [illegible] than [illegible] in field test plots of [illegible] [illegible].

5) Lysimeters provide a convenient and inexpensive means of studying the [illegible] behavior of soils under the various conditions of water and sew- age spreading. They may be valuable as aids in estimating the performance of large scale spreading operations.

ACKNOWLEDGMENTS

The studies reported herein were conducted in the Sanitary Engineering Research Laboratory of the University of California, Berkeley as a part of a research program on the fundamentals of waste water reclamation. The authors are pleased to acknowledge the assistance of [illegible] who performed the [illegible] and offered valuable criticism during [illegible] [illegible].

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

CONTENTS

DISCUSSION
(Proc. Paper 1003)

Note: Paper 1003 is part of the copyrighted Journal of the Sanitary Engineering Division of the American Society of Civil Engineers, Vol. 82, No. SA 3, June, 1956.

Discussion of "FUNDAMENTAL CONCEPTS OF RECTANGULAR SETTLING TANKS"

by Alfred C. Ingersoll, Jack E. McKee, and Norman H. Brooks
(Proc. Paper 590)

ALFRED C. INGERSOLL,[1] A.M. ASCE, JACK E. McKEE,[2] M. ASCE, and NORMAN H. BROOKS,[3] J.M. ASCE.—The writers are grateful to Mr. Camp for pointing out that the experimental data presented by him[5] for reduction of fall velocities attributable to hindered settling do not agree with the analyses presented by McNown and Lin.[6] Inasmuch as the latters' results are based on a theory, corroborated by experiments and also by theories of Burgers and Smoluchowski, the cause of the discrepancy is not apparent. The writers agree with Mr. Camp that further investigation is indicated.

The writers contend that it is definitely worthwhile to study the mechanics of sedimentation of suspensions of discrete particles, even though the sanitary engineer always deals with suspensions that are flocculent to some extent. Great progress is made in all fields of engineering by simplifying assumptions, especially those that lead to a better understanding of the physical phenomena. Even Mr. Camp in his earlier work[5] has made free use of the simplifying assumption of a suspension of discrete particles.

Considerations of discrete particles, however, will not solve all of the problems in settling tank design. A thorough investigation is now being made of the physical characteristics of domestic sewage under the direction of two of the writers with a grant from the United States Public Health Service. This study is specifically considering effects of flocculation and various test procedures on settling velocity analyses. It is hoped that the performance of settling tanks will be better understood when more is known about the nature of the suspensions being treated. When the results of this work are known, it is not unlikely that a new and rational procedure for assessing settling tank efficiency can be developed. Section III of the writers' paper presented what appeared to be a logical and simple approach to the efficiency problem in the absence of a good understanding of flocculation.

Mr. Camp has misinterpreted the writers when he infers that "the authors suggest that flocculent materials are more easily scoured" from the bed than non-flocculent materials. The writers should have stated that light, fine materials with small settling velocities are more easily scoured from the bed than Camp's scour formula would indicate, regardless of whether the particles are flocculent or not.

Research on the problem of scour of light materials is also presently underway at the California Institute of Technology under the writers' supervision with the previously mentioned grant from the U. S. Public Health Service. Even though the writers' analysis of scour is perhaps largely a matter of conjecture, Mr. Camp has still given no justification for extrapolation of

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Shields' scour analysis to bed Reynolds numbers much less than those used by Shields. Whereas Mr. Camp states that there is no reason why one may not extrapolate Shields' results, the writers believe that it was Mr. Camp's responsibility to show that there is a good reason why one can extrapolate. It is hoped that the current research will clarify the scour phenomena at very low bed Reynolds numbers $\left(\frac{d}{\nu} \sqrt{\frac{\tau_o}{\rho}} < 1.7 \right)$.

Mr. Camp states that in some experiments made by Langelier "where alum floc was settled with no scour at a channel velocity of 12 fpm, the friction velocity was 0.011 fps or some six times the settling velocity of a 0.1 mm particle with a specific gravity of 1.2." By an application of Stokes law for settling (assuming a spherical particle), the writers find that the settling velocity, v, is about 0.0035 fps at room temperature, or about 1/3 of the friction velocity instead of 1/6 as indicated by Mr. Camp. However, Mr. Camp's contention that, in order for scour to occur, the magnitude of turbulent fluctuations near the bed (or the shear velocity) must be several times the settling velocity, is probably correct.

Some recent experiments at the Valley Settling Basins of the City of Los Angeles have also indicated that the writers' suggested criterion for impending scour is probably too stringent. At this plant, a small amount of raw sewage has been treated with a heavy dose of alum and settled in two rectangular tanks each 300 feet long, 17.5 feet wide and 10 ft. deep (average). The horizontal velocities in the basins have varied from about 2 to 6 fpm. Fig. 16 shows the settleable solids in ml/1 in the effluent as a function of mean tank velocity. The critical velocity for resuspension appears to be about 4 fpm.

A rough pipette analysis of the alum floc shows that the median settling velocity of the particles is about 0.06 cm/sec, or 0.12 fpm. The ratio of tank velocity to median settling velocity at the commencing of resuspension is thus

$$\frac{V}{v} = \frac{4}{0.12} = 33$$

This ratio corresponds to a Z-value (exponent in the suspended load equation) of about 1.5, as compared with suggested design values of about 3 to 5. However, by visual observation of the effluent it was noted that many particles larger than the median were being resuspended, indicating that the critical V/v ratio is smaller (or Z larger). By comparison, the value of $\frac{V}{v}$ for critical shear is 57 for the example given by Camp from Langelier's data (see above).

The writers concede that their suggested criterion for incipient scour (V/v = 9 to 15) is probably unduly conservative; however, no reliable alternate recommendation can be made until more research has been performed. Nonetheless, the writers still believe that the resuspension of fine, light material must be directly related to the fall velocities of the particles, with the actual size and specific gravity of the particles being secondary.

Although the suspended-load equation cannot be applied directly to the scour problem, it does give an indication of how readily the sediment is diffused upward once it becomes scoured from the bed. When the exponent Z in

equation (11) is large (say > 3), the settling of the particles is so rapid that, for all practical purposes, the material is not even lifted into suspension; on the other hand when Z is small (say < 0.5), the particles settle slowly enough so that the natural turbulence is quite effective in diffusing particles upward toward the surface, resulting in a concentration profile in accordance with equation (11). If particles for which Z is small are readily available on the bed, then it is conceivable that large numbers of these would become suspended. The thin laminar sub-layer which separates the bed material from the main flow could not prevent suspension.

When a stream is in equilibrium the rate of deposition just balances the rate of resuspension; in a settling tank, it is desired to deposit as many solids as possible, with a minimum of resuspension. If there is resuspension, the concentration of suspended solids will be reduced only to the point where the rate of resuspension balances the rate of deposition. It seems reasonable to suppose that if the Z-value for the settling tank is too small, the resuspension will be impossible to prevent. The writers believe that Mr. Camp's statement, "Obviously, the suspended load theory is not applicable to impending scour," is not all justified.

Mr. Camp has called attention to the fact that residual turbulence in a settling tank resulting from the inlet may cause considerably more diffusion and mixing than the turbulence generated by tank friction. As this is very hard to evaluate quantitatively the writers have based the scour calculations on the turbulence caused by friction only, in the same way that Camp did in his analysis of the effects of turbulence on sedimentation.[5,9] Also, it should be pointed out that Camp's scour formula gives too high a value of the critical velocity if there is appreciable residual turbulence from the inlet disturbances. In this case the bed shear stress will fluctuate more than it did in Shields' experiments (or more than is natural), and a lower mean shear will cause some scour.

With regard to the harmful effect of the inlet jets in the Wisconsin and Purdue test tanks Mr. Camp states, "Most of the energy in the inlet jets is doubtless dissipated in the upstream end of the tank. . . ." This is exactly the function of the inlet baffle, to break up large-scale turbulence and by means of a head loss to gain a good distribution of velocity across the inlet end of the settling tank. In this design the slotted baffle serves the same purpose as the damping screens used in the settling section of a wind tunnel upstream from the test section. The screens induce a small-scale turbulence while destroying large-scale eddies, the idea being that the small-scale disturbance is quickly damped out and converted into heat by friction. Large eddies, on the other hand, can be carried downstream for a considerable distance before they are ground down into smaller eddies and finally dissipated into heat. While the turbulence induced by the inlet jets is seen to be of small scale, that arising from wall and bed friction is more likely to be of large scale, of the type that causes scour. Thus it is not uncommon in canals to observe eddies of a size comparable to the full depth.

The extent to which the turbulence induced by the inlet jets is damped out in the very first part of the tank is indicated in the researches of A. A. Kalinske[16] and H. R. Henry.[17] Mr. Kalinske has shown that for a three-

16. "Conversion of Kinetic to Potential Energy in Flow Expansions," by A. A. Kalinske, Trans. ASCE Vol. 111 (1946), p. 355.
17. Discussion of "Diffusion of Submerged Jets," by M. L. Albertson, Y. B. Dai, R. A. Jensen, and Hunter Rouse, Trans. ASCE, Vol. 115 (1950) p. 687.

dimensional jet in an abrupt (180°) pipe expansion the kinetic energy possessed by the turbulence is reduced to less than 1% of the expansion head loss within a distance of some 15 jet diameters downstream. The remainder of the head loss is dissipated into heat in the regions of high local shear immediately downstream from the jet. Mr. Henry's experiments on a two-dimensional sluice-gate (that is, a "half-jet") show that the energy of turbulence is reduced to about 0.5% of the head loss within a distance of 15 full-jet widths downstream.

Translated to the Wisconsin tank, in what is admittedly a fairly rough analogy, Mr. Henry's experiments would mean that 99.5% of the kinetic energy of the inlet jets (1/8-in. wide) is dissipated into heat within a distance of 2 inches from the inlet. It is difficult to believe that the remaining small-scale eddies could project their influence throughout the volume of the tank, so seriously affecting the settling process as Mr. Camp has suggested. It is perfectly true that the conventional type of inlet, with a single deflecting baffle, will produce large-scale turbulence which will indeed be felt throughout a short tank. The writers acknowledge the correctness of Mr. Camp's overall head loss calculations and there is no denying that the tiny fraction of the inlet head loss remaining in the form of turbulent eddies beyond the first few inches of the tank is still many times the loss from the drag on the floor and walls. However, the writers disagree with Mr. Camp's calculations of ratios of mixing coefficients. It is well known from Prandtl's theory that the mixing (or diffusion) coefficient is proportional to the product of root-mean-square of the velocity fluctuations <u>and</u> the mixing length. Comparisons on the basis of energy alone are misleading because the mixing length (or scale) is an important variable also.

The writers cannot agree with Mr. Camp in his solution to inlet design problems by simply making settling tanks so long that inlet effects are damped out by the drag on the floor and walls. It would surely seem that economics of construction might well dictate a shorter tank, having a well-designed inlet achieving good distribution without large-scale turbulence, than a long tank having a poor inlet. The flocculating-basin inlet is a step in the right direction, but not all settling tanks need flocculating basins.

The writers are indebted to Mr. Thackwell for his slant on making this paper more useful to the practicing engineer. As they pointed out in the paper, the writers are aware that existing data from operating plants do not support overflow rate (or surface area) as the sole design criterion for settling tanks. No more do they support detention time as a sole criterion. If all other factors can be evaluated, however, there is analytical reasoning to support overflow rate as the <u>principal</u> design criterion. The paper assumes this from the start, and then attempts to treat some of the secondary factors, notably inlet and outlet conditions, shape factors, and limiting horizontal velocities.

Mr. Thackwell has stated, "For any rectangular tank having vertical sides and a uniform depth, the detention time is directly proportional to the reciprocal of the surface area." For a fixed flow this statement is seen to be inverted, for then the detention time is <u>directly</u> proportional to the surface area.

The writers take exception on two counts to the design example quoted by Mr. Thackwell. First, the depth, detention time, and overflow rate are presented as though they were independent design criteria. Since they are not independent, but related by the expression, $v_0 = H/T$ for rectangular tanks, any two quantities will determine the third. (In fact, the values of detention

time (150 min.), overflow rate (0.074 fpm) and depth (9 ft) quoted by Mr. Thackwell are numerically inconsistent). Second, there is no reason to state arbitrarily the depth or the detention time. Instead, it is important to determine the limiting horizontal velocity, which must be established by considerations of scour. Then the length, width, and depth may be determined in accordance with the desirability of having a long narrow tank (preferably with length-width ratio of 10 or more) to minimize inlet and outlet disturbances, and the need for installing mechanical cleaning devices.

With regard to Mr. Thackwell's query about paradoxes in nature vs. occult factors inherent in the workings of sedimentation, the writers wish to point out that Mr. Thackwell has quoted them out of context. Taken in its entirety, the paragraph on p. 590-3, from which Mr. Thackwell has quoted, implies that the apparent disparity between the simple theories and actual performance is largely the result of the existing practice of considering per cent removal as a measure of settling tank efficiency. Section III, which follows that paragraph, attempts to remedy this deficiency by introducing a new concept of efficiency which takes cognizance of the settling characteristics of the influent suspension as well as the hydraulic geometry (overflow rate, detention time, etc.) of the tank.

The writers appreciate Mr. Thackwell's desire to have a few simple rules to guide the practicing engineer in designing settling basins. Beyond the simple approach given above, however, the writers have no reason to place further restrictions upon the latitude of the designing engineer. As more information becomes available from research and operating data on this subject, it may be that such restrictions will be warranted, but at the present time there seems to be no justification for prescribing design limits other than overflow rate and horizontal velocity (both fixed by characteristics of suspension) and length-width ratio (to be as great as practicably possible consistent with economics and mechanical cleaning). Additional launders at the effluent end of a long tank are also desirable.

Mr. Thackwell has proposed a scheme by which a plant operator may determine the quantity of chemical dosage he needs to coagulate certain raw waters for a given overflow rate and desired quality of effluent. It appears that two tanks of different shapes could be compared on the basis of the coagulant curves that Mr. Thackwell proposed if it were known that the influent suspensions to both tanks had the same chemical and settling characteristics. Thus the tank yielding the higher curve on the plot of removal vs. overflow rate for a fixed coagulant ratio would be considered the more efficient tank.

Waterworks chemists and engineers know, however, that coagulation of colored and/or turbid waters is a complex process that depends on many factors other than the concentration of color + turbidity. The coagulant dosage is governed by the concentration of many ions, by the pH value, by temperature, and by the type of coagulant being used. As Mr. Thackwell points out, his plan would be a means of guiding the operator toward greater economy in the use of chemicals, but it would not serve to compare sedimentation basins used for different raw waters.

The writers would like to express their appreciation for the thoughtful comments and helpful criticism offered by Mr. Camp and Mr. Thackwell in their discussions.

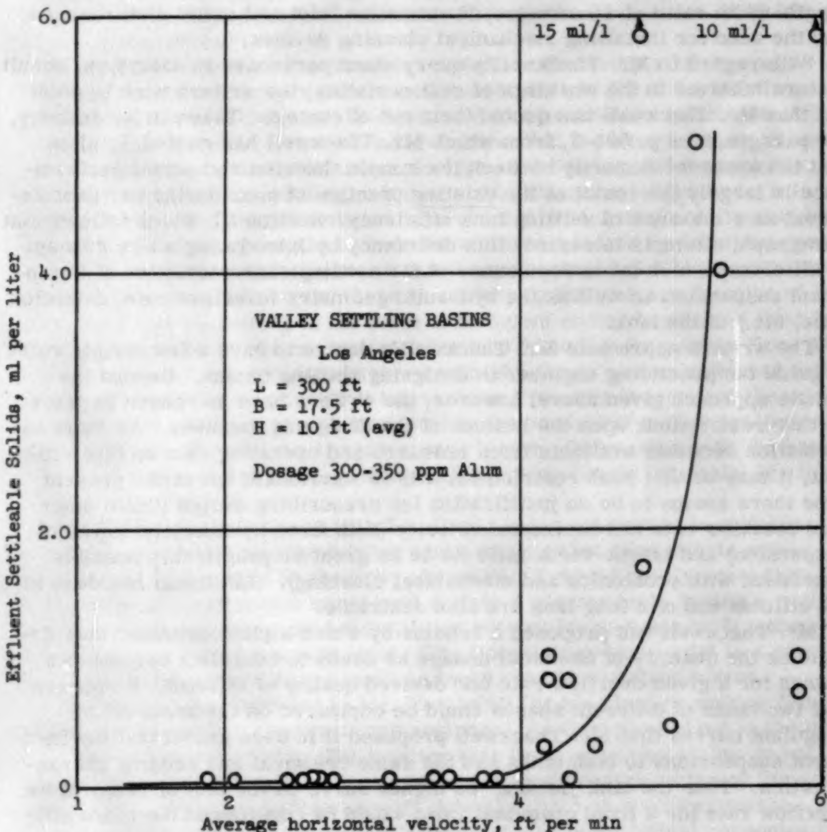

Fig. 16. Effect of Velocity on Effluent Settleable Solids

Discussion of
"SANITARY ENGINEERS—THEIR EARNINGS
AND PROFESSIONAL ATTITUDES"

by John C. Bumstead and Arthur D. Caster
(Proc. Paper 773)

ROSS E. MC KINNEY,* J.M. ASCE.—During this period of "engineering shortage" it is well to stop and examine sanitary engineering as a suitable profession. The authors have attempted to answer many of the questions posed by young engineers and to evaluate the professional aspects of the sanitary engineering field.

One of the major problems facing the engineering profession today is the confusion that exists in the minds of the junior engineers. Newspapers, magazines and radio are constantly warning the American public of the tremendous shortage of engineers and of companies grabbing off every graduate engineer at fabulous salaries. A good example of this type of propaganda is a statement in Time, Dec. 26, 1955, that "Georgia Tech's placement bureau, which will be sold out of 1956 graduates by May, is already taking orders for the class of 1957." The net result has been that recent engineering graduates expect high salaries and other benefits and tend to think in terms of what the company has to offer for their services rather than what they have to offer the company. Many young students are being forced into engineering, contrary to their aptitude, by the lure of security. A great disappointment for many graduates is the sudden realization that all branches of engineering are not faced with shortages and that high salaries do not come automatically.

Fortunately, sanitary engineering is not faced with quite the same dilemma as are the other branches of civil engineering. Very few students take up sanitary engineering with visions of riches. Personal contact with someone in the field is responsible for most if not all of the students taking sanitary engineering. Very few people have the correct impression of sanitary engineers and the scope of their field. This is reflected by the small number of undergraduate sanitary engineering curricula and students. Most of the sanitary engineering students are in graduate programs leading to a Master's degree. Motivation for graduate training lies in the type of work and the people in the field rather than in monetary rewards. This attitude is reflected in the satisfaction of the sanitary engineers themselves in their choice of a career.

It is not surprising to see that the major response to the authors' survey came from Junior Members. There has been a rapid increase in sanitary engineering graduates since World War II. Most, if not all, of these graduates have a definite awareness of the professional status of the sanitary engineer. They are just starting their careers and realize that advancement comes through effort expended and not merely from years of service. It is evident that the Junior Engineers know "where and why" they are going.

Degrees and salaries have never gone hand in hand and this is shown once

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again by the authors' survey. A degree does not confer ability upon the graduate but signifies only potential ability. Income can be more readily correlated with development of the potential ability. The Doctorate is primarily a research degree and is designed for those who wish to do basic research and to teach. Teaching and research in the sanitary engineering field will never challenge the top income brackets.

Engineering registration per se is not a cure all, though it has been called that, but it is important to the acceptance of the engineer. Registration is still a nebulous thing with regulations varying from state to state. Some states do not recognize graduate training as professional training towards registration, while other states will give partial credit. Yet, all states will recognize time spent on the drafting board in a consulting office. Registration can become a deterrent to increased education if the student is aware of these inequalities before he takes his graduate work. The student who spends three years or more getting a doctorate may know as much, if not more, than his counterpart in consulting, but registration boards do not recognize this fact. It is no surprise to find that many sanitary engineers holding doctorates are not registered.

The broad diversification of the sanitary engineering field also plays a factor in the percentage of sanitary engineers being registered. Many aspects of sanitary engineering (teaching, research, sales, public health and process design) do not require registration for active practice. Most states require registration only when structural design is required. For this reason there will always be a high percentage of sanitary engineers who will not be registered. Naturally the question arises as to whether or not these unregistered members of the field are really sanitary engineers. Certification attempts to answer this question by requiring that all certified sanitary engineers be registered engineers. There is little doubt that certification will tend to split the field into definite smaller areas rather than consolidating it. Instead of encouraging more chemists and microbiologists to enter the field, certification will tend to discourage them. These groups need recognition the same as the engineers themselves and will not accept a second class status in the sanitary engineering field.

Another factor in registration is that many consulting firms do not encourage their junior engineers to become registered. Registration is not required for employees in consulting firms and there a few incentives for registration. Promotions and salary increases could be used as the best incentives toward registration.

It was quite surprising to find that only 36 per cent of the sanitary engineers were dissatisfied with their salary. A recent survey[1] of chemists and chemical engineers in the New York area showed that 60 per cent of those earning less than $7000/yr. were dissatisfied. Dissatisfaction is not necessarily a bad sign any more than satisfaction is a good sign. The proper amount of dissatisfaction is required in any young engineer if he is to have the incentive to advance in the field. Too much dissatisfaction as well as satisfaction often means that the sanitary engineer is stuck in a rut and is making no professional advancement whatsoever. The future of sanitary engineering lies in the dissatisfaction of the junior engineer and in the accomplishments it produces. A person easily satisfied may not have set his sights high enough.

1. "How Does Your Current Salary Stack Up," Chem. Engr., 244-252 (July 19, 1955).

Sanitary engineering is a widely diverging field covering many disciplines. It is apparent that considerable confusion exists in the field for the lack of a proper definition of what sanitary engineering is. The scope of the field is such that the registered engineer is fast becoming a minority and is losing his identity. Certification has been proposed as the means for regaining proper identity. The acceptance of certification by the sanitary engineer means that registration has failed in its purpose of delineating qualified professional sanitary engineers.

Sanitary engineers can be divided into two major groups, engineers dealing with governmental organizations and those dealing with industries. The group dealing with governmental organizations will always be underpaid in relationship to the average engineering wages. No Federal, State of Local governmental agency will ever set the pace for engineering wages. On the other hand the group dealing with industries have salaries commensurate with those of other engineers of the same quality.

There are many aspects of the broad field of sanitary engineering and each engineer must strive to find his own satisfaction. The greater the effort made, the more recognition the profession will achieve. Sanitary engineering has made great strides during the past fifty years and will make even greater strides during the next fifty years. The rewards are there for anyone who applies himself diligently and wisely; for rewards do not come to those who sit around and wait.

JOHN C. BUMSTEAD,* M. ASCE.—The status of sanitary as well as civil engineers as revealed by recent surveys, which corroborate each other effectively, indicates much to be desired both from the standpoint of income and prestige or satisfaction values. These surveys reveal a certain lack of attraction, the result of which is being registered by a dearth of engineering students and a serious shortage of competent civil and sanitary engineer design and management-caliber personnel.

Recently an author writing in CIVIL ENGINEERING magazine referred to Gresham's Law (economics) which states that a cheaper money will drive a more valuable money out of circulation. The author then suggested that this might now be happening in engineering. While the parallel has been questioned, it has been a regrettable experience to have observed this action taking place in more than one organization: those without adequate training and experience have replaced qualified sanitary engineers who have found more rewarding work.

At the recent annual meeting of ASCE, it was reported that no more than 100 students were majoring in sanitary engineering in 1954. This shortage of new engineers plus the increasing need for sanitary engineers and the steady loss of promising sanitary engineers can only create a vacuum into which those without adequate training and experience are being drawn. Herein lies a serious threat to the maintenance (and raising) of the professional qualification standard.

Income Satisfaction

It is no secret that civil engineers receive the least compensation of all

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engineering branches. This fact has been brought out repeatedly in surveys, and it is unfortunate for civil engineering that this condition continues year after year with little improvement,—with little or no organized effort to correct it. This well-publicized condition certainly discourages good students from taking up civil engineering and causes significant departures of good men to more rewarding fields.

Recently in the New York Times Benjamin Fine writes that engineers with no experience whatsoever are picking up jobs at a salary of $400 per month. There is much comment that this salary is excessive for a new man. Yet these graduates are receiving about $2.30 per hour, the equivalent of a semiskilled worker.

The superior economic position of the skilled worker (coupled with lesser responsibilities) to that of the young engineer was brought to the writer's attention last summer. Two 'assistant' crane operators (oilers) received $7500 and $8300 in 1954. They have three and four years experience. Both of them received more in 1955 because of an hourly increase; both of them are quaranteed a 40-hour week with double time for structural work. Neither of them had to invest time and money and effort in a technical-professional education. But this survey shows that the sanitary engineer only gets into the $8100 to $9000 bracket after 16 to 20 years experience (Mode curve).

The survey shows that sanitary engineers generally are in the $4100 to $5000 annual salary bracket after four years of education and two years of experience.

Most of us in the early stages of our careers have gone through the 'unsettling' experience of serving as a field inspector or field engineer. We worked with many craft foremen and skilled laborers helping them and making their work possible and then found that they received substantially higher salaries than we did. When the progress of a construction job depends on the engineer's decisions and interpretations and he finds himself in a position inferior salarywise to those who actually perform the work, then the engineer's respect for his 'profession' can only be shaken. This situation has existed for a great number of years and probably will continue to be accepted without challenge, without an effort at improvement.

In our highly industrialized civilization, income is the principal measure of a man's material success. Right or wrong it is a concrete measure of his getting-ahead ability. Civil engineering, mainly because of the low income of its practitioners, is suffering from a serious deficiency both in quality and quantity. It is doubtful that there will be much improvement in this situation because of the high salaries commanded by the chemical, industrial and aeronautical engineers plus the prestige and opportunities for advancement that these fields provide.

Another factor, which bears on this situation, was recently uncovered by a survey of employment of engineers conducted by the director of placement of Northwestern University. Engineers generally receive higher starting salaries than any other job classification but after five years the commerce graduates are earning more than engineers and the liberal arts graduate who started much lower is earning considerably more than either the commerce men or engineers. What's more important is that the difference becomes greater as the years pass. This is significant because more and more engineers are finding a place in industry.

The engineer unlike the skilled worker has no aggressive organization to look after his economic and welfare interests. In this respect he is unique—

the engineer is in the middle. He has to shift for himself and maneuver to the best of his individual ability, sometimes against overwhelming odds when he is looking for a place to practice his profession.

The engineer is advised to act like a professional and to resist the pressure of unionism. He is given all kinds of 'pontifical' advice about being a professional man but when the chips are down and the unions threaten him and his livelihood and when he has to defend himself in court, the profession and its societies have failed him miserably; they have not come to his aid and comfort. Certainly if the young engineers accept unionism in one form or another, the engineering fraternity will only have itself to blame.

On the record, the guidance, protection and nurturing of the young engineer in professional development and responsibilities is dismal indeed. Starting in technical school, the engineering student very seldom is given the encouragement and being-a-part-of professional background that he should have for the practice of engineering. Then the years after graduation are too often filled with assorted jobs, assigned for production purposes rather than the training of the engineer. These jobs are not conducive to the development of the professional ideal because they are openly depreciated as being inferior, not of a professional caliber. And today these jobs are characterized by a 'remarkable' lack of supervision and guidance. The young engineer makes progress by a series of unnecessary trials and errors which professional supervision could minimize.

The lack of support and interest in the young engineer's development as he gains experience has been said to be one of the fundamental inadequacies of this field. Herein lies a challenge to the profession but those who would undertake a reform in this area will have to distinguish clearly between a technical agent for turning out plans and an engineer who can practice his profession creatively with confidence and respect. The type of work the young engineer does for his employer is important to his development but more important is the atmosphere and attitudes under which he works and develops.

The revered medical profession serves as a good example for engineers. Their men are accepted as doctors from the beginning; their standards are very high; they are taught to think like doctors; to be doctors; they are inculcated with a respect, admiration and devotion to their calling which is indestructible. All this gives them an immaculate, unbeatable confidence in themselves. Engineers need the same level of confidence.

Prestige Satisfaction

Professional recognition, as indicated by the survey, appears to be bothering sanitary engineers a great deal. They seem to feel 'unappreciated.' And in a sense they are: "You can hire technical brains a dime a dozen." I have heard this statement firsthand from responsible engineers. I am appalled by the short-sightedness of this abrasive attitude, by the devastating effect it has on employee engineers.

It is common knowledge among technically minded engineers that this attitude is prevalent in the profession and that the business, finance and promotional aspects are played up as superior interests. Certainly it must be conceded that engineering achievements are built on technical competence and engineering ability and that these achievements can only be implemented with sound business enterprise and effective public (or private) instruction.

Certainly it is high time that technical competence in this field be recognized and accepted as an equal partner with business ability in the practice of engineering. The technical engineer must be accorded his rightful prestige as one of the underlying incentives for his best work and personal advancement.

Young engineers, partly because of this depreciation of the technical function, are looking for a way out of the "technical morass." The writer knows of one young engineer, who, either through a misguided evaluation of his ability or through the realization of the low estate of technical engineering, demanded a managerial position after six months of experience. Whatever the reason, he eliminated himself from the practice of technical engineering at a time when there is a serious shortage of such engineers. (His salary was above the Mode of this survey).

Industry recognizes the fundamental contributions of the technical engineer and is making progress in providing essential prestige and recognition. While some engineers possess managerial talent, many of them (it is being discovered) are happier and contribute more if they remain in engineering and technical development. The past practice has been to reward good men by promoting them into management. But this has resulted too often in the loss of a good engineer and the creation of a poor manager. Now industry is setting up titles parallel to those of management to provide regocnition and prestige. And these technical experts and engineers are paid on scales equivalent to those of the management classifications. In some cases, the exceptional engineers are reported to be receiving more than the managers. The result has been greater satisfaction and greater achievement in the engineering categories.

This is an example that could be followed with profit by the civil engineering fraternity.

Engineers who can deal with the public and with clients, who can talk on their feet and defend and explain their projects, and who effectively represent the engineering profession are needed. So are the quietly competent technical engineers who provide the reliable designs, the sound plans and the controlling specifications, the 'stuff' of which engineering is made. Each must have the other and each deserves equal recognition and respect from the other. It is time that the technical engineer be given a prestige lift. It could be a mainspring of better work and encouragement for technically minded students to follow civil engineering. It would help those who now design and draw and specify without much enthusiasm. When one segment 'looks down' or deprecates another, the effect is to undermine the professional structure which is still a long way from completion.

Professional Recognition

Much confusion exists concerning the insufficient recognition accorded the engineer. The public has little concept of what a 'professional engineer' is and does. This is the fault of engineers themselves. They are reluctant to explain themselves and their work; some of them seem to prefer to deal only in concrete, steel, water and wastes. They are inarticulate. Lawyers speak up with great facility and are heard. Doctors are known through their intimate relationships with their patients. City councils may deal with a practicing engineer but once in a lifetime. Industrial management controls engineers in its employ and occasionally encounters an independent practicing engineer.

How then does the engineer gain this status called recognition? It cannot be obtained by fiat or legislation; it cannot be acquired by obtaining a handful of registrations; it cannot be drilled in by repeatedly using the term, 'professional engineer.' (Professional physician and professional attorney sound silly). It can only come through a long period of development during which the engineer grows in stature and respect, conducts himself with professional restraint and self-discipline, and contributes to the public interest and welfare.

Webster defines a 'profession' as "The occupation—if not purely commercial, mechanical, agricultural or the like—to which one devotes oneself; a calling in which one professes to have acquired some special knowledge used by way either of instructing, guiding, or advising others, or of serving them in some art." This definition is worth studying.

Engineers as a group have been too ready to dilute their standards by accepting unto themselves those who are not basically and truly engineers, such as technical specialists. This dilution, of course, does not strengthen the engineering profession and is unthinkable in the other older professions. Certification of sanitary engineers, if it is executed in compliance with the high moral standards under which it was conceived, could be the answer to assuring technical competence. The danger lies in the possibilities of dilution of the professional standards; even the registration laws have failed to keep engineering for engineers.

Too many engineers are unwilling to take examinations to prove their qualifications; yet for practicing physicians and surgeons this proof-by-test is an accepted way of professional life. To know that your physician is a specialist accepted by his colleagues commands your respect and confidence (and a sneaking admiration for the guy).

Engineering differs from other professions in that the impact of business and commerce upon it is great. In many instances these impacts develop into the guiding and controlling conditions. And the independence and critical judgment of the engineer is constantly challenged and pressured by commercial interests. How then is the professional concept to be applied, upheld? This is a question that each practicing engineer must answer each day for himself. Their collective action will then eventually determine if engineering is to be recognized and respected as a profession—or accepted as a business.

The close association of engineers with commercial activities, sale and purchase of equipment and the letting of contracts makes it difficult for the layman to think of an engineer as a member of a learned profession. To the public he seems like a man of business.

Engineers support a multiplicity of organizations ranging from professional societies to industry associations. This lack of unity through a single professional society is one reason for the lack of strength and recognition of engineers. In addition, every facet of engineering practice is served by well-financed industry associations which are more aggressive and more attractive business-wise than the several professional societies. Here again it is easy to lose sight of professional unity and professional responsibilities.

The employed engineer is a special problem, peculiar to engineering. He is subject to the direction of his employer, be he consultant or industry or government, and consequently is not free to exercise independent judgment in the full sense. He must be an advocate of his employer's interests and is an agent of his employer. While he may be trained as an engineer and think of himself as a professional man, the employee engineer occupies a somewhat nebulous position in the strict professional picture.

ARTHUR D. CASTER,* M. ASCE.—Of 1101 reporting 22 1/2% stated that they were dissatisfied with professional recognition, although many different terms can be placed on the two words "professional recognition." Certainly some thought and discussion should be given to the reasons engineers are dissatisfied with professional recognition.

Recognition of an engineer in a small community is no different than a large community except that in a small community the engineer has more opportunity to be in the public eye. In the Universities, the engineering professor gains recognition through written material. In a small consulting firm recognition usually is given because of the few numbers working therein. On the other hand, in a large town one must be really active (a go-getter) to be recognized publicly, or in a large consulting firm one must be of an outstanding ability to be recognized. Not all of us are willing to try. At the same time we must not kill off the initiative or enthusiasm of the young engineer.

What Makes an Engineer and How Long Does it Take to Make an Engineer?

After reading Engineering articles concerning the young engineer who graduates from the Universities today, and his problems, suggests the following:

That a conscientious effort be made to contact the universities and through other organizations impress upon the Professor the need of instilling into their potential graduates what an engineer is; does, what is expected of him, what makes him a professional man; the purpose of "Engineers in Training" and full registration. Through this effort the young graduating engineering students may come to realize that his "Engineer in Training" experience is actually an internship similar to a Doctor, Lawyer or C.P.A.

We cannot adequately perform this mission, but it is our feeling, that it takes the actual Professor who deals daily with the young student to accomplish the above mission.

Remember that a Doctor spends two to four years as an intern, if he survives, before he opens up his practice. A young lawyer is a "runner" for many years before he is able to hang out his shingle. In some law firms, with 5 or 6 names as partners, there may be 100 or 150 "runners" who never are recognized by the public. The engineering profession deals in public services with public officials normally, or private firms; wherein a doctor or dentist normally deals with individuals or the single public, this is an entirely different catagory than engineering. Possibly we should have the definition of the term "professional." (Definition) Adj. 1, pertaining to a calling or occupation requiring a superior education, 2 following a calling as a means of livelihood.

Noun: One who makes his living by an occupation, as distinguished from an amateur.

We all like to use the term "professional engineer" probably to define ourselves from operative engineers, locomotive engineers, refrigeration engineers or stationary engineers.

If we are tieing professional recognition down to salaries, in order to increase salaries, then we should take a different tack. In accordance with the salary survey of the N.S.P.E. and the A.S.C.E our salaries are no different

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in the ranges for experience than other engineering groups throughout the country. Only today every man is taking a different philosophy, especially the young engineers, than those of a generation ago in which experience was desired with a living wage. Now we are all out to get everything we can NOW and not twenty years later. This thought has been instilled, the writer believes, because of the Unions. Industries pay for experience, and how do you get experience? Books and a college education will give a part of the working tools, so to speak, in order to understand the practical side. Citing several instances of this, a young engineer in our office and only 3 months out of school complains that he has not yet been given any authority in the office, although this same person is not considered an engineer as he has failed his "Engineer in Training." The writer firmly believes that for a man to direct other people, he must at least have done some of the work that he is trying to tell other people to do. After all, not all engineers are considered managerial or boss material. We are remembering that the apparent shortage of engineers have led to abuse of engineers, but at the same time has placed a premium on graduate engineers. In review where engineers are going today it has been found that Aircraft Industries hire between two to five times as many engineers as they need and are using same as technicians. The shortage of Sanitary engineers in consulting firms is largely due to the expanded accelerated program of sanitary facilities. Again we have a shortage of highway engineers because of the increase Express and Turnpike work throughout the country and from all apparent use this shortage will continue for a number of years.

At least the survey, right or wrong, as to interpretation, has caused considerable comment in several sections of the country and as a result of the survey two consulting firms have adjusted their salaried upward. As a member of the Inter-Society Committee of the NSPE, the writer suggested than an over-all master questionnaire be prepared by the Joint Council and the N.S.P.E. probably four or five pages in length, in which we would receive answers from all kinds of engineers throughout the country in sufficient quantity to adequately interpret the various problems before us today. In the past two years we have filled out five different salary and satisfaction surveys and it is our thought that if all of these can be brought together under one common heading, then the engineers will have something to talk about to the management, to the Government, and among themselves.

Discussion of
"EXPERIENCES WITH A NEW TYPE OF DAIRY WASTE TREATMENT:
Progress Report of the Sanitary Engineering Research Committee,
Industrial Waste Section"

(Proc. Paper 847)

JOHN B. ROWNTREE,[1] A.M. ASCE.—The dairy industry is one of the largest in New Zealand and the working out of an economical method of treatment for the wastes is consequently of great importance to the country. We have been most interested in the methods described, in the paper but unfortunately the excellent results now quoted far exceed those reported to us as being indicated during a personal inspection of the plant.

In view of this and in order to clarify the matter could the Committee note:—

1) What is the condition of the creek into which the effluent is discharged?

2) Has any difference been found between winter and summer operation?

3) Are the results quoted those from weighted samples over 24 hours?

4) What odours are there round the plant?

5) Are the 5 H.P. motors still in use or have they had to be replaced by larger ones?

6) How much supervision is required to keep the plant operating efficiently?

7) Has this type of treatment yet been approved by the relevant State Department as suitable? Have they any comments?

1. Designing Engr., Auckland Metropolitan Drainage Board, New Zealand.

Discussion of "SANITARY PROGRAMS OF THE ICA IN THE NEA AREA"

by Vincent B. Lamoureux
(Proc. Paper 885)

A. STREIFF,[1] M. ASCE.—The "new colonialism" so vividly described in one of its phases by the author, more and more becomes a carbon copy of the old colonialism. Recently it has for the first time been admitted publicly that "trade can be increased without a system of oppressing other peoples." The purpose now unfolds as the same old struggle for markets; the same old "deals;" the same division of territories, the same consternation when another power invades the region. In previous eras American enterprise in other countries was strictly on its own, often in competition with other nationals subsidized by their governments. Under the new colonial system this country has disbursed subsidies on the greatest scale ever witnessed in the scramble for hegemony in trade. Thus, in the region under discussion by the author, in particular Iraq, we find in the New York Times of January 16, 1955 the caption: "Oil-wealthy Iraq like a boom town; U. S., British, French, German concerns compete bitterly for contracts and orders."

As the author graphically describes, the new era finds this government organized on a larger scale than any of the colonial offices of other governments ever was. It has been costing the American taxpayer untold billions. In contrast with a well-organized civil service under the old colonial system, our effort has been one of temporary engagements, of troubles to find competent personnel, of failures and adverse publicity. The author describes in particular the sanitary field. In this specialty the writer's own experiences in the forgotten past are here recounted. They provide a perspective different from that of the author.

The description of the sanitary conditions given by the author certainly are appalling. In the writer's mind, if they were really as bad, he would not be here now to tell the tale. One begins to wonder how it would be possible under the appalling sanitary conditions, for the Asian peoples to survive at all, let alone overrun the world in fantastic numbers. Let us take an example. The island of Java has nearly the same area as the State of New York. Since 1825 its population has increased from some four million to fifty million, while during the same period New York State, in spite of the greatest metropolis in the world, and intensive industrialization, barely reached fifteen million.

The writer lived for nearly two decades in an Asian tropical city of some 300,000 population prior to the year 1900. That is prior to the great strides in medicine and sanitation, in the eradication of plagues which since have come to pass. In this great city there was no watersupply system. There was no sewerage. In other words, it was about as the author describes it.

Here, such conditions would create a panic. The Health Authorities would quarantine the town. A state of emergency would be declared.

What were the results? The writer as well as his environment led healthy

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1. Cons. Engr., New York.

lives, with scarcely an ill day during all those years. Of the children's diseases, only measles. Ninety degree heat did not stop teen agers from playing Rugby football. But many decades afterwards his children, born and reared in the State of Michigan, with all the advantages of modern sanitation and the greatly improved state of modern medical science, exhausted the catalog of children's ills from mumps and whooping cough to scarlet fever, jaundice and even a case of tetanus.

How were such results possible? The answer is very simple. And exceedingly low in cost. It was already given by Herodotus in 450 B.C. Describing the campaign of Cyrun, the Persian king, he states: "Wherever he travels, he is attended by a number of four-wheeled cars drawn by mules, in which the water from the river Choaspes which flows by Susa, ready boiled for use, and stored in flagons of silver, is moved with him from place to place." The water was boiled for drinking purposes. But in addition there were other factors equally important. Dispersal of dwellings, free air, outdoor life, light clothing—as Kipling calls it, the "thin kit"—much shade in a sunny climate, bathing twice daily and a healthful diet with abundance of fruit were equally important.

Water was obtained from an open well in the rear garden of the dwelling. The wells were round, brick-lined, some six feet in diameter and shallow. The water table was not far from the surface of the ground. The water was contaminated but clear. It was strained through cloth into a copper vessel and boiled. It was then filtered in a filter cut from porous limestone placed on a support under which a porous earthenware vessel was located to collect the filtrate. The porous receptacle kept the water cool. That was all. The bath house consisted of a cement and brick building containing a rectangular open tank of some 600 gallons capacity with dipper for a "manually operated" showerbath. Water from the well was used without further treatment. Instead of sewerage, a brick and concrete building containing a number of privies was connected with the main dwelling by a covered, concrete passage way. Such were the conditions which enabled this writer to grow and thrive in a tropical climate without illness. In addition the white man had long since abandoned unsanitary western habits and adopted native ways.

It should be kept in mind that in spite of our elaborate present systems of watersupply, it is still necessary to use complicated machinery for the sterilization by the means of chlorine. In the above simple system no chlorine was needed, or used.

Such a system could not be applied here, but with exception of the boiling feature is still in use here in thousands of small rural towns and farmsteads. With three million square miles of wide open spaces available, our sanitary requirements are built around the needs of the jampacked standard big city, three-dimensional beehives of crowded humanity with canyon streets out of reach of the sun's ultraviolet. Watersupply and sewerage have been taken care of, but air pollution is left to scavenging by the winds. When these fail, actual deaths from air pollution have resulted; we can not live in an aerial sewer. But we are so accustomed to the jampacked factory city, the foul air from thousands of cars, trucks, busses, incinerators, and chimneys, the dust, the soot, the polluted streams, that in our own minds the "city with a thousand smells" is the non plus ultra of modern perfection, and from the author's description we are now about to introduce its blessings into the hapless "underdeveloped countries."

The most common human foible is to notice everything in strange surroundings and forgetting all about identical conditions at home. Many of the remarks of the author can be transferred without change to our metropolis. He says: "the ignorance is not due to a lack of intelligence but to a lack of educational opportunity for the masses." Currently a clean-up campaign of littered streets is being waged here with little effect. The author stresses that animal manures are allowed to accumulate. There must be perhaps a million dogs in the metropolis, in a sanitary sense equal to perhaps a quarter of a million humans. Their refuse is allowed to be deposited on street pavements and sidewalks until in many of these one literally has to tread one's way, through what amounts to an open sewer. The refuse dries, is ground by traffic to dust and inhaled by the milling crowds. Spectre of the black lung! If there are any black lungs in any of the Asian countries, it has escaped publicity.

The author stresses the prevalence of disease, but much of this of course is not related to sanitary engineering. The battle against disease has been continuous, limited only by government and the status of medicine. It is exactly fifty years ago to the day that the writer witnessed the closing through cure of a "framboesia" detention camp through the use of Ehrlich's 606, then just discovered. "The Odyssee of an American doctor" written a generation ago by one of the Rockefeller Institute's scientists is another illustration of the microbe hunters, which have come from many nations. Many of the plagues were only a memory long before ICA, UNESCO, FOA, MSA, or ECA and the recent conquest of trachoma by aureomycin is not due to our methods of sewage disposal or watersupply.

To one born and reared in the East the constant reference to "underdeveloped" nations appears inaccurate. Civilization was born there; all its fundamentals, originated there came to high development. The white man's superiority in pure and applied science is not apparent until five centuries ago, or even less. The resulting infiltration and conquest is now in reverse. What the results will be of the new crusade described by the author is for the next generation to experience.

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Discussion of "PLANNING SEWERAGE SERVICES FOR SUBURBAN AREAS"

by Ray E. Lawrence
(Proc. Paper 892)

GEORGE W. REID,[1] A.M. ASCE.—These remarks should be prefaced by stating that Mr. Ivan Shull, Sanitary Engineer, Kansas State Health Department, and writer have operated as a task force to study for the Public Health Committee of the ASCE, "The Development of Sewers in Fringe Areas." The assembled preliminary findings have been transmitted to the chairman of the committee, Mr. Dwight Metzler, and will be published as a committee report. It should also be stated that Mr. Shull's and writer's participation in this initial study were made possible through the assistance of the USPHS of which Mr. Shull and the writer are both commissioned officers. Consequently, the writer does not propose to reveal the Task Force findings, but to draw on them only as is required to discuss Mr. Lawrence's paper and to express these as his own opinions—not the committee's.

Lawrence has done an excellent job of presenting the consulting engineer's problems associated with the development of sewerage in fringe areas and view point towards their solution. The reference delineating scope of the problem to the 168 standard metropolitan areas, the writer feels should be expanded, in that small urban fringe areas are also so affected, the solution applicable to larger areas should generally be good for small areas. The problem arises out of the scattered growth on the fringes of central cities and remains so until the population density reaches a figure that will permit the economical development of sanitary sewers. Lawrence has suggested 1.5 persons/acre. This "leap frog" development and the attendant sewerage problem is typically American. In Europe, land use and planning methods demand that areas be developed in orderly consecutive sequence, thus making it economically feasible to complete sewers as the areas develop. The writer is opposed, as nice from a purely engineering standpoint as is appears to be, to this type of control, and as a consequence must cast about for methods of financing, operating, and designing sewers in the confusion of typical American expansion. There does not appear to be a standard approach to the problem, but solutions vary with the local laws, and methods of financing. One time honored solution, the septic tank, definitely is not the answer because of the insistance of the public as well as public health agencies on sanitary sewerage systems. The recent tendency to develop large groups of houses rather than lots at one time has been largely responsible for this.

Many engineers and planners advocate a solution by annexation by the central city and the control of fringe development by the sale of utilities.

This, of course, is essentially, the European system. Lawrence notes that this is not always practicable because of the implied obligation of providing the same municipal services enjoyed by the remainder of the city. This need not be the limiting factor, services and taxes can be scaled as services are

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developed along with the areas. Many muncipalities in Oklahoma which own the utilities are utilizing this technique.

Lawrence has described two solutions, both being employed in Johnson County; the private developer, and the county sewer districts. These solutions are being used all over the country, and work, but they do have definite disadvantages. The private developer has to be a "big operator" and willing to deviate from his prime purpose to go into the design, construction, and operation of sewage disposal systems. The county sewer districts are encumbered by Statutory limits, legal boundaries not necessarily coincident with drainage areas and lack of organization for operation of sewage facilities. Lawrence has noted, quote "the need for enabling legislation to provide greater flexibility in organization, development of long range plans, and the financing of sewer districts on a drainage area basis."

The drainage area concept is vitally important. This leads logically to another pattern which is used in Ohio and could be employed in other states, namely, the conservancy district. This technique not only insures development on a drainage area basis but also make possible the inclusion of other basin wide functions, such as flood control. Much justifiable criticism has been leveled at the development of too many specific districts or authorities for each function of metropolitan government such as the metropolitan sewer districts. Some metropolitan areas, such as Detroit have solved this problem by developing city-county contracts for sewer services, but this appears awkward.

One plan, which is currently being tried in Toronto, and shows considerable promise is called Federation in that it answers most of the objection to other methods. Herein the communities in a metropolitan area band together to form a Federation to handle all services common to the metropolitan area, including water, sewage, arterial streets, parks, etc., and reserving strictly local functions for each community. This is similar to our Federal government's relation to the states.

In any event, which ever pattern is used, one fact remains clear, and to quote Lawrence, "Many cities have found that some problems can be avoided by careful advance planning." The author believes this to be the number one need; namely, the Implementation of a Master Sewer Plan. This implies not only activity by engineers but cooperative action on the part of planners and legislators. As an example, certainly, all groups should consider Lawrence's recommendation that enabling legislation permit districts to issue bonds without a vote.

Certainly there are some strictly engineering problems involved. Lawrence has noted the increased flow in sewers, and resulting changes in design criteria. The peaks should also be studied, particularly in the street lateral where there appears to be so little information. Stage development presents problems and the concept of temporary treatment might well have added to Lawrence's sequence of events, using such devices as oxidation ponds, etc.

Lawrence has certainly pointed up a problem beyond the purely design consideration, involving organization, legislation, financing and planning as well; a problem which certainly will get worse, and a problem whose solution appears to rest clearly in the collective lap of the professional groups involved.

Journal of the
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ENGINEERING JOB OPPORTUNITIES IN WORLD HEALTH

Hershel Engler[1]
(Proc. Paper 1012)

We as Americans can travel our country over and from one end to the other and feel safe as we mingle with people, drink water, eat food and sleep snugly. This has not always been the case, however. Furthermore, this situation does not exist in most areas of the world today.

Wilson in his book "One-half of the People" states that "more than 2-3/4 billion people live in the world today and 2 billion of them are sick. In another quarter century unless the pattern changes we can expect a population of 3 billion with 2 billion or more sick." It can be brought closer to home when we realize that during World War II, more than one third of our manpower of military age were judged physically unfit for military service.

The Director General of the World Health Organization has stated that "probably three-fourths of the world's population drink unsafe water, dispose of human excreta recklessly, prepare milk and food dangerously, are constantly exposed to insect and rodent enemies, and live in unfit dwellings."

The problem is well summarized by Dr. H. van Zile Hyde, Chief, Division of International Health, Public Health Service, in his statement "The major health problem of the world today is not death as it was during the great historic pandemics of cholera and plague and in our lifetime, influenza. It is chronic and repeated infections and infestation which converts man from a productive unit of society to a liability to society."

The question might well be raised, how does this all affect us as Americans? With modern transportation facilities, where whole population groups can be moved from one continent to another in a short space of time, where vectors and foci of disease can likewise be moved, the health problems of one continent become the concern of other continents. More important is the "American way". Most of the ills plaguing mankind today can be controlled and it is "our way" to show and help them.

The awakening of international health consciousness probably stems back a short 100 years. Some of the worst ravagers of mankind–cholera, smallpox, yellow fever–long since written off as controllable by the medical and allied sciences–were on the loose in the middle of the last century. In fact

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we today are again faced with a possible threat from yellow fever which is creeping northward from certain areas in South America. Throughout the years, various governments called conferences to combat these epidemics. During the middle of the last century, medical officers were in conflict with a wide difference of opinion on the process of contagion. The science of bacteriology had not yet been developed. Pasteur was still working in his laboratory, ridiculed by many. There was the Paris conference of 1851–again in 1859; Constantinople in 1886; Vienna in 1874. The only concern of the health conferences was the effect of epidemics on trade and there was always the politically dangerous word, surveillance. In 1876 the U. S. Government called a centennial international medical congress in Philadelphia, at which Dr. John M. Woodworth of the Marine Hospital Service (now the Public Health Service of the U. S. Department of Health, Education, and Welfare,) submitted his now famous six "propositions", the last of which read: "The endemic homes of cholera and yellow fever are the fields which give the greatest promise of satisfactory results to well-directed and energetic sanitary measures, and to this end an international sentiment should be awakened so strong as to compel the careless and offending people to employ rational means of prevention." In 1881 during another international sanitary conference in Washington, Dr. Carlos Finley of Cuba advanced his theory that an as yet unidentified carrier was responsible for yellow fever. His daring co-workers in Cuba continued experimenting and eventually convicted the Aedes aegypti mosquito. The day of the sanitary engineer in the world scene was rapidly approaching. Preventive and curative medicine were moving towards alliance for the betterment of mankind.

The spread of diseases, which ravage mankind, knows no limit. At the present time there is no way of knowing how bad are conditions of world health. Vital statistics are either inadequate or nonexistent in areas where prevalence of disease and population density are greatest. However, some estimates can be made based upon available knowledge. It is estimated, for example, that there are or were until recently in the world 300 million cases of malaria per year, and 50 million cases of tuberculosis. In some countries from 50 to 80% of the population are either syphiletic or infected with protozol and worm infections such as hookworm, filaria, the flukes, leishmanious, the dysenteries and many others. The total list, of course, is much longer. It is difficult for us here in our day to realize that three fourths of the people of the earth are still without sanitary environment, undernourished and burdened with disease. Many or most of the destroyers of mankind are diseases of the environment, controllable through accepted sanitary practices, properly applied. The sanitary engineer plays a very important role in this control.

Through international programs of our government and the multilateral organizations such as the World Health Organization, the United Nations Children's Fund and the Pan American Sanitary Bureau, a real opportunity is afforded the sanitary engineer to contribute in some small or large manner to the stabilization of world tensions and the improvement of international relationships between all countries. Here now exists an opportunity for us as engineers, on a world basis in the field of public health, to contribute the fruits of our training and experience for the betterment of mankind.

There are many agencies engaged in international health activities. Through the United Nations, the concept of international health has found its most potent means of expression. The multilateral approach to public health

–in which the resources of many nations are mobilized for the common good– is found in the programs of the United Nations and its specialized agencies. These include the World Health Organization, the Food and Agriculture Organization, the United Nations's expanded technical assistance program for underdeveloped areas, and the United Nations Children's Fund.

With a limited total budget for the world-wide activities of the World Health Organization and the Children's Fund, only a small and inadequate amount can be allocated to environmental sanitation activities. In December of 1951, only 75 persons including physicians, entomologists and public health engineers and sanitarians were assigned to World Health Organization technical assistance activities. In 1955 there were over 55 engineers and sanitarians alone employed by the World Health Organization in some 85 countries. In order to obtain the maximum benefit from the limited personnel available, the World Health Organization has directed its efforts principally toward such activities as:

1) Collection and exchange of scientific and technical knowledge by expert committees, expert panels, and scientific conferences.
2) Training of national personnel by assignment of demonstration teams.
3) Training either by traveling fellowships or by enrollment in formal academic courses.
4) Strengthening of training facilities.
5) Short-term expert consultation on specific problems.

The World Health Organization operates as an autonomous unit within the United Nations framework. Its programs are conceived in the field jointly with the governments concerned, planned and directed at the regional level and coordinated at the headquarters level in Geneva. Close cooperation is maintained between the United States bilateral programs and those of the World Health Organization.

The United States experience with the bilateral approach–a direct arrangement between two nations–had its first trials in the health field during the last war through the Office of the Coordinator of Inter-American Affairs. The foreign ministers of the American republics, faced with the potential problems of an all-out war, requested cooperation among the republics on health and sanitation problems. This eventually resulted in the creation of the Institute of Inter-American Affairs, which did much in the field of public health for our neighbors south of the border.

With the close of the last war accompanied by the world-wide expansion of trade, commerce and the development of foreign ideologies, our country saw fit to expand upon a program to aid the efforts of the peoples of the economically underdeveloped areas, to develop their resources and improve their working and living conditions by encouraging the exchange of technical knowledge and skills, to effectively and constructively contribute to raising standards of living in these areas. This action created the Technical Cooperation Administration (Point IV), later to become the Foreign Operations Administration and now the International Cooperation Administration of the Department of State in which are centered all of the foreign aid activities of our Government. The Public Health Service of the U. S. Department of Health, Education, and Welfare is the primary source of recruitment for personnel to staff the public health programs of the International Cooperation Administration.

The sanitary engineer in both of the multilateral and bilateral programs

devotes his activities to improving the conditions of the environment as a means of reducing the prevalence of communicable diseases.

In the bilateral program, the basic health team in any country mission consists of a public health medical officer, a sanitary engineer, a public health nurse, a health educator and a health administrator. Generally the largest programs in any mission are in the field of environmental sanitation. In most instances the medical officer is chief of the field party. In some instances the sanitary engineer is deputy chief. In 8 of the 43 countries in which health programs are operated, sanitary engineers are chiefs of the health mission. We, as members of the profession, take pride in this delegation of responsibility and acknowledgement of the role of the sanitary engineer in the health field.

The American Society of Civil Engineers encompasses a group of engineers engaged in a wide range of activities. I have constantly referred to sanitary engineers throughout this paper. It might be well to define the term as recommended by the Subcommittee on Personnel and Training of the Committee on Sanitary Engineering and Environment of the National Research Council as it is very applicable to engineers serving in international health: "The professional occupational title 'Sanitary Engineer' shall apply to a graduate of a full four-year, or longer course leading to a Bachelor's or higher degree at an educational institution of recognized standing with major study in engineering, who has fitted himself by suitable specialized training, study, and experience (a) to conceive, design, appraise, direct, and manage engineering works and projects developed, as a whole, or in part, for the protection and promotion of the public health, particularly as it relates to the improvement of man's environment, and (b) to investigate and correct engineering works and other projects that are capable of injury to the public health by being or becoming faulty in conception, design, direction or management." The practice of sanitary engineering includes the preparation or making of surveys, reports, designs, reviews, direction, management, operation, and investigation of works or programs for water supply, waste disposal, milk and food sanitation, housing sanitation, insect and vermin control, camp and recreation sanitation, air pollution, radiological health, and any other factors having as their major objective the control of the environment affecting health.

The first World Health Organization Expert Committee on Environmental Sanitation defined the term environmental sanitation in broad comprehensive terms. Basically, it embodies all of the above activities of a sanitary engineer. Subsequent committees and consultants felt that the definition was not sufficiently broad because it limited control of environmental factors to those which exercise or may exercise a deleterious effect upon man's well-being. It was, therefore, suggested that the definition of environmental sanitation be expanded to include activity for the conservation and development of natural resources to raise the standard of living in any community. It can be seen that this is a rather broad definition but provides a real challenge to the trained and experienced engineer.

As Dr. Hyde has pointed out in his many papers on international health, the leadership and participation of sanitary engineers in these programs have been of major importance. There are few health programs that assist in the development of interest in health more than does the installation of a water works system. In our 15 years of experience in bilateral programs in health, the work of the sanitary engineer has done more to develop certain

areas in Latin America than any other program. The provision of better water, proper waste disposal and food sanitation control, accompanied by sizeable reduction in many of the debiliating diseases, has given impetus to economic, cultural and political development never before experienced in these areas. While the amount of U. S. assistance has been nominal, the total amount expended by recipient countries for health activities has been considerable. For example, from the initiation of the Latin American program in 1942 through June 30, 1951, a total of $107 million was expended for health projects. Of this amount, $67 million was contributed by the host country and approximately $40 million contributed by the Institute of Inter-American Affairs. Of this amount, approximately $30 million was expended for 661 sanitation projects. The above is typical of many areas of operation. In some of the programs, U. S. contribution is as little as 10% and sometimes less. The entire program is generally under the direction of U. S. personnel with host country technicians serving alongside for training. During the past year, the programs in three countries were turned over to the host country for operation with American personnel remaining to serve as consultants for a short additional period of time.

The scope of some of the sanitary engineering programs in foreign countries staggers the imagination. In India, for example, a five-year national water supply and sanitation program is under way. It involves the organization and staffing of public health engineering organizations throughout the country, the training of 1,000 public health engineers, 250 sanitarians, 1,500 overseers, 3,200 sanitarian aids. The objectives are to bring under control the water and filth-borne diseases such as cholera, the dysenteries, typhoid, hookworm and Guinea worms which take an annual toll of some 2 million lives and cause 50 million cases of illness. Can you conceive of a program designed to provide within 5 years for some 550,000 villages 1,650,000 wells, 55 million latrines and 625,000 tons of cast iron pipe?

In the administration of health programs in foreign lands, one of the basic problems confronting the sanitary engineer is his place in the over-all health picture. In the Americas, the sanitary engineer is recognized as an integral part of any health program. Unfortunately, this is not so in most areas of the world. Some countries that have a high degree of competence in the medical field are yet wholly inadequate in the field of environmental sanitation. One of the basic objectives of our overseas programs is the establishment of a sound sanitary engineering structure within the host government, preferably within the health ministry.

The U. S. technicians serving overseas generally serve as consultants to the host governments. In instances where adequately trained personnel are not available within the country, U. S. technicians actually operate the program until trained personnel becomes available. One of the basic requirements is for host country personnel to work alongside American technicians in order to be able to eventually take over the program.

One of the large programs of the health missions and part of our foreign aid program is the selection and provision for training of foreign nationals.

The following figures show the number of sanitary engineers from 39 countries programmed by the Public Health Service for graduate training in the United States:

1950 -	9
1951 -	33
1952 -	15
1953 -	60
1954 -	36
1955 -	54
Total	207

The World Health Organization also assists in graduate training by offering fellowships to selected personnel. The following shows the number of environmental sanitation personnel (world-wide) given graduate training by the World Health Organization (not necessarily in the United States):

	Jan. 1947 to Dec. 1951	1952	1953	1954
Environmental sanitation	97	77	52	44
Housing and town planning	1	-	1	-
Food control	6	4	12	5
Totals	104	81	65	49

It becomes apparent that there is still a great shortage of trained sanitary engineers throughout the world.

The challenges and opportunities for sanitary engineers in international health work are many. Some of their activities include:

1) The development of various excreta disposal devices constructed of variously available materials in different environments, devices adapted to the prevailing economy and cultural tradition of an area.
2) Th development of economically feasible potable water supplies for isolated dwellings and villages in tropical areas.
3) Design and installation of water and sewerage systems in towns remote from usual sources of materials, as in Central Africa or the Amazon basin.
4) The unsolved problem of effective schistosomiasis control.
5) Prevention of health hazards in the development of impoundments and irrigation systems.
6) Control of insect borne diseases among essentially nomadic populations.
7) Milk sanitation in tropical climates among peoples who have no comprehension of the causes of diseases.
8) Control of food handling and eating place sanitation in tropical and semitropical areas with primitive or no refrigeration.
9) Design and construction of sanitary slaughter houses and market places adapted to indigenous customs.
10) Development of sanitary engineering curriculums in schools of engineering.
11) Development of sanitary engineering administrative structures in governments.
12) Training of sanitarians in accepted practices of environmental sanitation.
13) Development and operation of sanitary engineering laboratories.
14) Development of necessary sanitary engineering research pertinent to the problems of the country.

The total number of engineering personnel in both the bilateral and

multilateral programs is very small. The World Health Organization has 55 sanitary engineers and sanitarians serving in some 85 countries. The United States in its overseas health programs has 65 professional engineers serving in 43 countries. In support of these professional engineers, there are 38 additional professional and semiprofessional sanitation personnel designated as sanitarians who are trained in the biologic sciences and public health. There is need, however, for many more in both the bilateral and multilateral programs. At the present time there are up to 40 vacancies for sanitary engineers and sanitarians in the world-wide programs of the World Health Organization. In addition there are up to 20 vacancies for similar personnel in the U. S. programs overseas. The picture is fluid, replacements are continuously needed and new programs are being developed.

American technicians going into the field are chosen not only for technical competence but for character, personality and ability to work with people of other countries. Before leaving the United States, these technicians receive training at the Foreign Service Institute in Washington as well as from the technical agency directing their program. Their training is designed to give them an understanding of the customs, cultures and problems of the people in the country in which they will work and an understanding of our foreign aid aims and objectives. The type of program in which they engage varies from country to country depending upon local conditions and the environment.

It is difficult for us to realize that there are cities larger than Dallas, Cleveland and Washington without piped water supplies, underground sewers, refrigerated food and pasteurized milk; places where we as Americans would not eat in a public restaurant. These places are many, both near and far from us. If we are to develop friends for "our way of life" we must share our technical advancements with them.

There is still so much to be done. There are countries where the infant death rate is 500 and more per 1,000 births. In some areas, one half of the children die before they reach the age of one, and one half of the survivors die before they reach the age of five. Much of this is due to water, food and insect-borne diseases and is preventable with modern sanitation. Our country's overseas health programs are not monies wasted but are investments for the future. What better way can the sanitary engineer serve humanity, his profession and his country!

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Journal of the
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ADVANCES IN SEWERAGE IN THE PERIOD FROM OCTOBER 1, 1954, TO DECEMBER 1, 1955:

Progress Report of the Committee of the Sanitary Engineering Division on Sewerage and Sewage Treatment

This report was prepared as one of a series of sub-committee reports of the Committee on Sewerage and Sewage Treatment and relates specifically to matters of sewerage; to wit, the collection of sewage and industrial wastes. Other sections to be reported upon are: primary treatment, secondary treatment, sludge disposal, financing and legal aspects, and specialized subjects.

Changes in sewer design and construction rarely occur with suddenness and almost never with the fanfare that sometimes accompanies new developments in sewage treatment processes and in sludge disposal methods. Sewerage changes are evolutionary and, while resistance to innovation is great, nevertheless, this past year has seen certain changes and advances in sewerage which are of interest to the profession.

Advances in Sewer Design and Construction

Of recent years, several new materials for sewer construction have been tested and in some few cases applied to sewers having pipe diameters from 4" to 8" . Transite, Orangeburg, and plastic pipes have been suggested for use in sewer construction, but have received only a modicum of experience, largely because of cost, lack of familiarity with new pipe laying techniques, the absence of assured long life, and the limitation to the smaller pipe sizes although transite pipe is available up to 36" diameter with both simplex and ring type coupling. Inertness to acid attack is usually the prime consideration in use of these materials, but in the smaller pipe diameters, clay pipe is usually available at lower cost and is highly resistant to acid attack. One advantage over clay pipe for these new materials still remains their greater resistance to shock with less chance of fracture. The tightness of joints may differ among the several materials, but jointing compounds or seals can usually be successfully developed.

One of the recent advances in the design of clay pipe has been the use of polyvinyl chloride molded gaskets in bells and spigots to effect a water-tight

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seal, thereby minimizing infiltration, exfiltration, and root penetration. Polyvinyl chloride is relatively inert to acids, alkalies, and oils and greases and is, therefore, quite satisfactory for sewage and industrial wastes. At present, some four years of experience seem to indicate that the joints are time-stable; however, extended periods of use will be necessary before the anticipated life of the joint may be accurately determined. Advantages of the polyvinyl joint are stated to be as follows:

1) Labor saving advantages in pipe jointing, making it possible to lay a 50-foot section of line in less than 10 minutes.

2) Ease of jointing in wet conditions, making it possible to lay the pipe in submerged trench conditions, this having been accomplished by divers using self-contained underwater breathing apparatus in at least one instance.

3) Flexibility of jointing to provide protection against shock, vibration and backfill loads. Up to 1" deflection per foot of pipe length to avoid construction difficulties or effect large radius bends. A section of the joint is shown in Figure 1.

To make the joint, the gaskets are lubricated with a soap solution and pushed together by hand or pry bar. The joint snaps together and is so constructed as to remain under compression after the joint has been formed. Uniformity in manufacture is said to be insured through the use of polyvinyl chloride castings accurate to .005". These are made an integral part of the pipe by a special adhesive; for cut lengths a union is used for jointing.

At present, clay pipe with polyvinyl chloride gasket rings is available in the East in sizes from 4" through 15" diameter and will shortly be available on the West coast in 4", 6" and 8" sizes. It is not yet available in western Canada. Present costs for the special joints are said to be from 10 cents to 15 cents per inch of inner diameter of pipe per joint.

Reports from the American Water Works Company and water works managers in New England (1) who have used Carlon plastic service pipe are summarized as follows:

1) There have been no failures of the plastic pipe of the type now being used.

2) No trouble has been experienced with the bronze adaptors.

3) Difficulty has been experienced with the metal bands which clamp the pipe to the adaptors, the trouble being in the nature of stripped threads on the screw, or a broken band. Experiments are now being made with a so-called Bandit Tool.

4) Plastic pipe is a non-conductor and therefore cannot be thawed by electricity. This has brought objections from prospective users in the colder climates, but may not be a factor in use for sewers.

5) The pipe has to be carefully laid, as it is subject to crushing or cutting if laid in a rocky trench and carelessly handled. The pipe does not uncoil and stay put like copper, but is springy and men have to stand on it to hold it down until partially backfilled. All made the comment that the pipe is being used experimentally and its limited period of use does not permit an honest opinion of its value.

Plastic pipe has more elasticity than lead or copper and so may be better able to cope with water hammer. It becomes very soft and plastic at about 270° F.

Experience with jointing clay pipe and concrete pipe with oakum and portland cement joints is stated by J. C. Oliver, City Engineer, to have met with considerable success in the City of Vancouver, British Columbia. In the larger sizes from 30" in diameter and up, rubber gasket joints have been used and are proposed to become standard for jointing the larger pipe sizes.

A French publication[2] mentions observations made at open-air sewer pipes where white efflorescence occurred on the pipes and the joints fractured with linear cracks starting from the female part of the joint. Analysis of the efflorescence suggested the avoidance of use of portland cement for joint construction and recommended the use of tarred cord and bitumen. It was further recommended to use well-fired and perfectly vitrified pipe.

Experience in Detroit with sulphur-compound jointing material[3] has indicated that pipe corrosion and failure was largely caused by internal stress caused by the rigidity of sulphur-compound joints. The strain was stated to be caused by variations in temperature.

Reporting upon jointing of pipe in the Winnipeg area, N. S. Bubbis suggests that the use of poured plastic joints should be made a more general practice; however, the city has used poured joints only on boulevard streets to overcome root troubles. Difficulties with cement joints are stated to result from the following reasons:

1) The use of portland cement with subsequent attack by calcium and magnesium sulphates and carbonates in the corrosive soils. This may be alleviated by using alkali-resisting cement.

2) Contractors not putting sufficient cement in mortar and caulking the joints properly.

3) Tree root troubles developing by roots penetrating the joints.

Reporting upon New York City practice, S. W. Steffensen, Chief, Bureau of Sewage Disposal Design, states that the Department of Public Works uses extra strength vitrified clay pipe for the branch intercepting sewers from the regulator chambers to the main intercepting sewers. The sizes used are generally 12", 15" and 18" in diameter. Over 18" in diameter, precast reinforced concrete pipe is used. Two types of joints are specified:

1) Gasket of hemp or oakum with portland cement mortar for pipe sewers above the normal ground water table.

2) Gasket of hemp or oakum with hot poured asphaltic compound for pipe sewers below the normal ground water table.

The branch intercepting sewers are generally short in length and of shallow depth of excavation compared to the main intercepting sewers. Actual leakage has been well within the allowable. Clay pipe is supported on a concrete cradle or, where necessary, is fully encased in concrete.

S. W. Steffensen, further reports upon experience in New York City concerning joints for a precast reinforced concrete sewer pipe and states that, whereas, formerly mortar joints were used exclusively, results obtained were not uniform and depended somewhat on the manufacturer of the pipe and to a greater extent upon the contractor doing the work. Some contractors obtained tight joints; others did not. Several years ago experiments were begun with a rubber gasket and portland cement mortar type joint. The specifications required that the pipe be made tight by the rubber gasket without depending upon the mortar which is placed in the joint spaces on both the

inside and outside of the pipe. The rubber gasket is of the corrugated "L"-shaped type. The short leg of the "L" fits over the shoulder of the spigot as an aid in holding the gasket in place during the jointing operation. In the manufacture of the pipe it was required that perfectly machined castings be used to form the tongue and groove ends of the pipe in order to assure true circles, thus providing a uniform annular space for the gasket. At first no mention was made as to how the tongue and groove ends were to be formed, with the result that many ends were out of round. The trade has been indoctrinated, and at the present time no difficulty is encountered in securing excellent pipe locally from at least three different plants. When the pipe is laid, it is required that the shoulders of the tongue and groove shall be no more than 1" or less than 1/2" apart for pointing up with the cement mortar. The presence of some gap assures that in bringing the pipe "home," the pressure will be on the gasket. Pipe is furnished in lengths of eight feet or more.

The rubber gasket is applied to the spigot 24 hours before laying the pipe. The outside surface of the spigot is given a heavy coating of rubber cement. The rubber gasket is then stretched over the spigot end and properly placed on the wet rubber cement. After one length of pipe has been joined to another, the position and condition of the gasket is examined from the inside of the pipe before successive lengths are installed. If the gasket is found to be in an unsatisfactory position or condition, the pipe is removed, and the operation of drawing the pipe together repeated with a new gasket.

The use of rubber gaskets has resulted in very tight sewers as found in the construction of the Oakwood Beach Intercepting Sewer, where a total length of approximately 16,000 linear feet of pipe was laid in sizes of 48", 54" and 60" in diameter. The average depth of the excavation was 23' with ground water elevation about 2' below the surface of the ground. The actual leakage was 11.9 gpm against an allowable leakage of 73 gpm, based on a tolerance of one-half gallon per hour per inch of inner diameter for each 100 feet of sewer. It is interesting to note that there was no leakage at all in the 60" and 48" sizes, and only 10 joints out of 611 joints of the 54" size leaked. The leaking joints were subsequently made tight. This type of joint has been used successfully also in the intercepting sewers for Owls Head (North Branch), Rockaway, Bowery Bay Extension, and Pt. Richmond (Rector Street).

For large precast reinforced concrete sewers flowing under slight pressure, extensive use of the steel ring and rubber gasket type joint has been made in New York. Allowable leakage for this type of pipe is usually 40% or 50% of that permitted for gravity sewers. Actual leakage by test is extremely small.

S. W. Steffensen, adds that for the first time the Department of Public Works, City of New York, has specified a prestressed reinforced concrete cylinder pipe with rubber gasket and steel ring joint for the construction of the 20" diameter Conner Street Force Main. This pipe, Class 150, conforms to the AWWA C 301-SST Standard Specifications. The contract was only recently awarded and construction has not started as yet. The manufacturer has assured the Department that the pipe has 3-edge bearing strengths of 5,000 lbs. per linear foot (0.01" crack) and 7,500 lbs. per linear foot (ultimate load). The leakage test will be made by the internal pressure method with a hydrostatic pressure of 150 lbs. per sq. in. maintained for 8 hours. The allowable leakage is 75 gallons per inch of diameter per mile of pipe per 24 hours. Standard lengths of pipe are 16 feet. The Department of Public Works

will watch the construction of this type of pipe for force main with great interest for comparison with more conventional jobs.

The Department of Public Works, City of New York, has permitted, in the place of extra strength, vitrified clay pipe as originally called for in the contract for the Oakwood Beach intercepting sewers, the use of 18" diameter, precast reinforced concrete pipe manufactured by the "roller suspension" process. This pipe is centrifugally spun and uses an inner roller and vibration to insure a uniform distribution of aggregate and true wall thickness. The pipe was provided at no extra cost to the city. Not only was this pipe able to stand greater loads than the extra strength, vitrified clay pipe and the standard strength precast reinforced concrete pipe, but fewer joints were required as the pipe was manufactured in 8-foot lengths. The pipe is designed for an ultimate test load of 6,000 lbs. per linear foot, based on the minimum strength of 4,000 D, D being the internal diameter in feet. The joint used was a rubber gasket and 1:2 portland cement mortar joint. The actual leakage was 0.022 gallons per min. against the allowable leakage of 0.92 gallons per min. The branch intercepting sewer where this pipe was used was 615 feet long, the average depth of excavation was 17.0 feet, and the ground water level 2.0 feet below the ground surface.

The jointing of sewers in the City of Denver has been stated by C. P. Gunson, Superintendent, to be in the form of two standard joints; one, a cement mortar joint, and the other, a hot poured plastic joint. In general mortar joints are laid in dry areas and hot poured plastic joints are used where the sewer pipe is laid in wet areas. When the joints are properly placed complete satisfaction has been experienced.

Experience with rubber gasket joints in Gary, Indiana, is recounted by W. W. Mathews, Superintendent. In 1939 and 1940 the Gary Sanitary District laid approximately ten miles of precast concrete pipe in the intercepting sewer system which ranged in size from 42" up to 108". The joint was the bell and spigot type and rubber gaskets were used in making up the joints. The rubber gasket used was like a plain rubber band with small fins on it and the bell and spigot were both coated with rubber cement before the gasket was placed on the spigot end. The pipe was then pushed home to final setting and the joints were pointed up with mortar using EMBCO as an additive. On checking the infiltration on approximately 3-1/2 miles on a 72" and 84" intercepter where the ground water level was over the top of this sewer except at the outlet, it was found that for all practical purposes this sewer was bone dry. There was approximately 3/4" of water flowing in the 84" sewer which represented the infiltration over the mileage noted above. Experience at Gary, where no repairs of any kind had been required on this precast pipe with rubber joint over a period of 15 years, has convinced city officials that this is an excellent type of construction and if properly done insures a minimum of infiltration.

J. C. Oliver, City Engineer, reports upon an interesting system of storm and sanitary sewer design developed in the City of Vancouver, B. C. where the need for storm sewers deep enough to drain basements and to serve each house is quite apparent when one considers the annual rainfall of 55 inches. In Vancouver, storm and sanitary sewers are constructed in the same trench with the storm sewer overriding the sanitary sewer and passing through the same manholes in such a manner as to provide access for cleaning both pipe lines. Original designs were such that storm water spilled into the sanitary channel at manholes; however, recent design as indicated in Figure 2 has eliminated this difficulty.

Estimates and experience show that such systems can be constructed for two-thirds of the cost of sanitary and storm sewers in separate trenches.

Sewer Maintenance

Sewer maintenance programs have, in the larger sewerage systems, become almost universally established on routine schedules. Experience shows that an over-all reduction in sewer maintenance costs can be effected if sewer cleaning is done on a scheduled basis to prevent stoppages rather than to correct them. Full advantage can be taken of the fact that a few sewers will require little or no attention, while others, which would quickly clog if unattended, can be more frequently cleaned. More and more use of the sewer ball in cleaning small and medium diameter sewers is evidenced while sewer plows, go-devils and patented rodding or augering devices are commonly used in the larger trunk sewers. Los Angeles, Winnipeg, St. Boniface, and the Greater Winnipeg Sanitary District report good results from the use of portable radio-telephone equipment in cleaning between manholes where sight obstructions would make hand signaling difficult or impossible.

In recording sewer cleaning techniques used in the City of Denver, C. P. Gunson, Superintendent, states that the former procedure of rushing crews to the point of a clogged sewer and rodding the sewer clean proved unsatisfactory. Instead of waiting for trouble to happen, a record of the clogged sewer was maintained and analyzed to indicate which locations stopped up more frequently than others. A preventative maintenance program was set up, whereby, the points that stopped up most frequently were flushed at intervals. It was found that if the sewer was flushed at certain intervals, plugging was almost eliminated. After a trial run of the flushing, it was decided to put on additional flushers, and the entire city sewer lines are flushed at uniform intervals. Some points are flushed twice weekly, other points weekly, and some points only once a month. This flushing program has reduced the plugging of sewers and has actually reduced the maintenance cost of sewer cleaning.

S. W. Steffensen reports upon the cleaning techniques used for outfall sewers at New York City. The 72" diameter outfall sewer for the Coney Island Pollution Control Plant extends a distance of 8500 feet from the plant to the diffusion chamber in Rockaway Inlet. The capacity of this pipe is important as backing up causes a release of plant effluent into a local waterway known as Shellbank Creek. By 1950 the flow and frictional resistance at Coney Island had both increased to a point where spillage into Shellbank Creek at high tide was occurring frequently. The Hazen-Williams co-efficient of the pipe had dropped below 100, whereas 110 was considered a safe allowable minimum with the increased flow.

The outfall was first cleaned in 1951 and subsequently in 1953, 1954 and 1955. An additional outfall line is undergoing design. Until the new one is in operation, the Department will apparently have to clean the old outfall of its slime growths once a year. Each cleaning consists of passing a cleaning machine through the pipe, one, two or three times until the co-efficient is restored to 140 or better.

The cleaning machine is 8' - 6" long and made to the diameter of the pipe. The chassis of the machine consists of 4 steel rings, slightly smaller than

the diameter of the pipe, which are held together by rods and spacers. On the first and third rings, wheels are mounted to fit snugly into the pipe. At the front ring is mounted an adjustable conical closure so designed that the amount of water passing the machine may be pre-determined; thus the driving force may be controlled. A continuous series of spring-like fins is also attached to the back of this front ring to form a seal against the inside of the pipe. This combination of cone and fins is known as the driving head or piston. Spring-mounted street-cleaning brushes are attached to the second ring and spring-mounted rubber squeegees to the fourth ring. The device has gone through several changes before evolving into its present form.

At the beginning of the cleaning operation, the machine is lowered into the specially built cleaning manhole and jacked into position. The sewage pumps are started, causing plant effluent to enter the outlet system. As sufficient head is built up, the device is started on its way. The machine is discharged into the diffuser chamber from which it is removed by barge-crane and diver. The travel time for its course of 8500 feet is adjusted by cone opening and rate of sewage flow to an optimum of about one hour.

The cleaning machine is rented from the National Water Main Cleaning Company. The work is done by a combination of City forces and a private contractor working under the direction of the owner of the machine.

Characteristics of Sewage

There has probably resulted a larger change in the characteristics of sewage in the past five-year period than in any other five-year period during the previous half century. This has been occasioned by the substantial use of kitchen garbage grinders in some areas and the increase in the wastage of water from air conditioning systems in others. Experience in Los Angeles County shows that kitchen garbage grinders will about double the grease load in sewers and will create minor problems in the pumping and treating of sewage-garbage mixtures. Such problems do not suggest a need for curtailing garbage disposer installations, but do indicate need for modifying the design and operation of certain facilities. The problem created by the clogging of gas traps with grease, thereby stopping the flow from lateral sewers, has caused the County Sanitation Districts of Los Angeles County to inform all local sewer authorities tributary to the Districts' system that sewer gas traps can, and should, be removed permanently from all local sewers except where actually proved necessary because of odor problems in the lateral system.

W. A. Dundas, General Superintendent of the Sanitary District of Chicago, has stated that in the Sanitary District the increased consumption of water for air conditioning has created a significant demand during hot weather and feels that the discharge of this uncontaminated water to the combined sewers will encroach upon sewer capacity. He suggests that perhaps a completely separate system for conveying air conditioning wastes may be desirable in certain highly centralized areas to provide ready re-use of this already treated water and eliminate the capacity demand on the sewers.

In Los Angeles County this problem appears to be intensified because of the separate sewer system which provides little, if any, capacity for increases in flow above those predicated upon conventional residential and industrial flows. A thorough survey of the air conditioning field reveals that

the smaller air conditioning units, rated from fractional horsepower upward to about five horsepower, may be effectively and efficiently air cooled without the need for water cooling. Industry representatives feel that this trend is well established and will continue because of the freedom from maintenance and lower cost of installation enjoyed by air-cooled air conditioning units.

In units of five horsepower or larger it becomes economical to utilize water cooling for the refrigerant condensers; however, this may only be done in the Los Angeles area if conservation of water is practiced through use of cooling towers or evaporative condensers. Because of these facts, the Los Angeles County Sanitation Districts found it desirable to reaffirm its policy prohibiting the discharge of uncontaminated water to the sewer.

The Districts' statement of policy is as follows: "Storm waters or uncontaminated waters of any origin are not considered appropriate for discharge to the Districts' trunk sewers." For those cooling systems which utilize cooling towers or evaporative coolers, the Districts' policy states further, "Blow-down or bleed from cooling towers or other evaporative coolers, equalling not more than 1/2 of the evaporation loss (1/3 of the make-up) are acceptable in the sewer. Where cooling is done by using only heat exchange without utilizing evaporative cooling, the waste water must not be discharged to the sewer."

Alternative to the disposal of cooling water to the sewer are the following:

1) Discharge to appropriate storm drains or drainage channels.
2) Discharge to a dry well located on the premises.
3) Utilization of air-cooled units wherever practicable.
4) Utilization of water conservation devices such as cooling towers or evaporative condensers, from which a maximum of one-half the evaporation loss or one-third of the make-up water will be accepted for discharge to the sewer.

T. R. Haseltine reported on the effect of ground garbage addition to sewerage systems and sewage treatment processes and concluded that ground garbage may not present serious problems to sewerage systems which are functioning satisfactorily prior to addition.(4) Where solids deposition and putrefaction have been encountered, such problems will be intensified by the addition of ground garbage. The installation of central grinding stations should be preceded by careful consideration of all factors related to sewerage systems and the treatment facilities. The inevitable steady growth in the number of domestic grinders requires careful consideration of expected changes in the composition of sewage as incurred by the addition of ground garbage. Changes in the nature of sewage due to ground garbage and their effect on treatment processes are reported in detail.

Following a study, Kerwin L. Mick, Chief Engineer of the Minneapolis-St. Paul Sanitary District, reported on the effects and costs of garbage grinding on sewage treatment. The effect on total volume of sewage flow will be minor, increasing less than 2% even if all garbage from homes and commercial establishments is ground to the sewer. The strength of the sewage will be increased, but the increase will be gradual and in proportion to the rate of grinder installation over a period years. It is anticipated that cost per ton to handle the garbage solids will be higher than for normal sewage solids. At $4.00 per ton, the estimated cost to the Sanitary District for disposing of this ground garbage is stated to be $1.28 per home grinder per year.

C. P. Gunson, Superintendent, reporting on the effect of ground garbage on sewers at Denver, Colorado, states that garbage grinders are a relatively new thing in that city. In 1948 there was an ordinance making it unlawful to install garbage grinders. This ordinance was rescinded and since that time there has been some 20,000 garbage grinders installed. The only place where difficulty has been experienced at all is where the house is located at the very end of a sewer. The last three or four houses connected to a sewer may have some trouble in that the solids settle out and the water drains away, allowing the ground garbage to adhere to the sewer walls. If no further flushing takes place before the ground garbage dries out, some difficulty may be experienced in the building up of dry solids. This is the only noticeable effect that garbage grinders have shown on the sewer lines in Denver.

Protective Lining

Much interest and controversy has surrounded the question of protective lining of concrete pipe. Protection against acid attack from the generation of hydrogen sulfide gas through the action of bacterial slimes is usually stated as the principal reason for use of protective linings. In years past, such linings were developed from glazed tile liners which were plastered to the crown of the sewer with what was hoped to be a fairly inert cement. Experience gained in the use of such installations in many locations has shown that such liners usually loosen and ultimately fall free from the surface, leaving the underlining concrete exposed to sulfide attack. No experience has been available concerning the more recent developments in the field of vitrified liner plates; however, certain improvements have been made during the years which may lessen the obvious drawbacks of this type of protection.

Vinyl plastic sheets have been developed which are cast integrally with the pipe and held in place by T-shaped ridges of plastic on the under side of the coating. With the plastic liner extending from below the water line in a continuous sheet over the crown, the underlying concrete is protected against the direct attack of the sulfuric acid resulting from hydrogen sulfide generation. Problems associated with the use of this type of plastic liner relate to the joining of plastic sheets at pipe joints to prevent intrusion of acids behind the liner plate; the difficulty of protecting manholes and junction chambers; and the danger of infiltration of ground water into the area between the plastic liner and the concrete pipe, with the possibility that the liner will be pulled completely free from the crown of the sewer.

Although protective lining of concrete pipe is considered by some to be an effective answer to the problem of sulfide generation in sewers, others are convinced corrosion is only one aspect of the problem of sulfide generation and that the confining of sulfide gas in an inert underground tube serves to intensify the problem of odor and other nuisances at points where the sewer must be vented. To this end considerable research has been expended on the mechanics of sulfide generation in sewers in attempting to solve the problems of sulfide generation. Chlorination of sewage to destroy dissolved sulfide has long been practiced and is an effective, although expensive, means of eliminating sulfides. Recent studies in the Los Angeles area have demonstrated the feasibility of controlling sulfides in sewer force mains through the introduction of compressed air. One such installation operated by the Los Angeles County Sanitation Districts is used to prevent sulfide build-up in a 2.14 mile long force main, 54" in diameter, carrying an average daily

flow of 28 mgd. With an average BOD of 458 ppm and an average temperature of 74° F., the injection of 90 cfm of air through a diffuser tube located some 15' from the sewage pumps on the discharge side suffices to oxidize the dissolved sulfides in the force main and usually yields a dissolved oxygen content at the terminus of the force main.

N. S. Bubbis, General Manager, Greater Winnipeg Sanitary District, reports that experience at Winnipeg shows that corrosiveness and high alkalinity in local soils required the adopting of a standard practice of making all concrete sewers of alkali-resisting concrete. Where disintegration of concrete sewers appears to be local due to bacterial formation of sulfides, acid resistant Ciment Fondu has been used in conjunction with almost pure silica sand. Granitic aggregate is recommended to minimize sulfide attack.

Stutterheim and VanAardt have reported on corrosion of concrete sewers and some possible remedies(5) and have summarized their findings in the following generalized statements:

The corrosion of concrete sewers is due to sulphuric acid formed by microbiological processes from hydrogen sulfide liberated by sewage. The above water portion of the sewer is corroded while the underwater portion is little affected. The study of the problem was divided into three fields:

1) To find if sewer design could be modified so as to result in reduced sulphuric acid production;
2) To find if any link in the chain of microbiological process could be broken thus stopping or reducing the acid production;
3) To find if the resistance of concrete to acid could be increased.

Field studies show that:

1) There is no obvious relationship between age, type and septicity of sewage and corrosion.
2) Ventilation of the sewer has no beneficial effect.
3) A clear correlation exists between corrosion and turbulence, and between corrosion and hydrogen sulfide concentration.
4) At points of high turbulence more hydrogen sulfide is released, thus more acid formation.
5) Hydrogen sulfide is generated mainly in slime and silt deposits and not in flowing sewage.

Studies on the resistance of concrete to corrosion showed that if the aggregate is made up of acid soluble material such as limestone or dolomite, instead of acid insoluble material, the life of the concrete is greatly lengthened. It was shown further that with acid soluble aggregate the entire material was attacked and not just the cementitious matrix, thus there is about five times as much basic material present to neutralize the acid. The rate of destruction thus should be only about one-fifth that of regular concrete. With dolomite aggregate the calcium sulfate attack was also greatly lessened.

Studies of the microbiological process are reported in a separate paper.

Mr. G. G. Cillie, Municipal Biochemist, Paarl, South Africa, has stated that their experience suggests the possible application of calcareous aggregates such as limestone for use in sewer pipe construction to provide a larger proportion of alkaline substance to neutralize the sulphuric acid formed from sulfide generation.

Sewage Pumping Plants

N. S. Bubbis, General Manager, has stated that practice in the Greater Winnipeg Sanitary District has been to design sewage pumping plants with separate wet and dry wells, feeling that this gives better opportunity for equipment maintenance. It is also preferred that stations be built with super structures rather than underground for simpler maintenance. Ventilation is considered particularly important to prevent condensation and as a safety measure for those servicing the pump station.

Topeka, Kansas,(6) has developed a coordinated plan for 7 sewage systems discharging to a single treatment plant. The city has 20 lift stations equipped with 44 non-clogging pumps. Eleven of the stations are underground and are fully automatic units which are furnished complete, ready to be lowered into place in a water-tight steel tank with an entrance tube at the top. Two operators care for these eleven stations. Each station contains two 4" non-clog sewage pumps; the 7-1/2 hp motors are started and stopped by air purge type controllers activated by the sewage level in the wet well. Alternate operation is effected by an automatic sequence change. Dehumidifying ventilation systems are used to prevent damage to equipment from moisture and sewage gases. A special hydraulic ram device keeps the stuffing boxes of the pumps lubricated. One pumping station is located in one of the nicer neighborhoods of Topeka and boasts pumps of 4500 gpm, 7500 gpm and 15,000 gpm capacity with quarters for the operator in a building that is architecturally compatible with its surroundings.(7)

The use of siphons in pumping plants was described in the literature(8) with examples showing data and descriptions being given. One of the uses of siphons stated is that of preventing back flow of a pump when it is shut down. A siphon is lower in cost and maintenance than a back flow valve for a moderate size pump.

The literature describes difficulties encountered by the City of Baltimore in outlying areas due to power stoppages and overflow at pump stations.(9) The policy of the City of Baltimore is described with regard to standby power, visual signals, high water alarms, and increased storage capacity.

The use of a "radio watchman" at a sewage pumping station in Hopkins, Minn., is described in the literature.(10) Because of small size, overloaded capacity and inflexibility in design of the existing pump station, monitoring of the station must be continuous and reliable. A "radio watchman" changes audio tones into light signals which monitor the plant and are intercepted at the city hall 4 miles distant. Radio is considered more reliable than telephone because of floods and subsequent power failures.

References relating to the design of pumping plants appeared in the literature (11, 12); these present to the reader some observations on the design of pump stations as well as procedures for estimating present and future capacity needs.

An interesting means of preventing the corroding of submerged electrodes used in controlling the rate of discharge from sewage pump plants is described in the literature.(13) Scum formation in wet wells had created a maintenance problem and made accurate control difficult. A plastic beach ball attached to the end of the pipe housing the electrodes is the basis of the design. The beach ball creates a closed vessel and the pipe is filled with fresh water. In this manner the electrodes are always submerged in water

and no scum can form to interfere with the controls. The water level in the tube fluctuates between the proper levels through the expansion and contraction of the plastic beach ball.

Experience with a new type of non-clogging solids pump is stated by the Los Angeles County Sanitation Districts to have met with considerable success. The Districts purchased and installed their first non-clogging vortex type solids pump with recessed impeller mounted completely out of the flow path manufactured by Western Machinery Company, in December 1953. Figure 3 is a schematic section through the pump. This pump was used in pumping raw sludge from a battery of sedimentation tanks to a sludge conditioning tank. The unit replaced had been clogging at least once per day, but since the installation of the vortex type pump there has been no interruption in service due to clogging.

The second such pump was placed in service in September 1953 and is used for digester cleaning. A heavy sand load is handled along with rags and other debris usually found in the scum blanket in a sludge digester. Other centrifugal sludge pumps tried for this duty clogged at least once per shift; however, the vortex flow pump has operated without service interruptions due to clogging since installation.

A third such pump was placed in a small sewage pump station handling domestic sewage. When the pump was installed in September 1954, the bar screen was removed and it has operated continuously to date without a service interruption due to clogging, whereas the unit replaced was clogging two to three times per week.

In addition to the previously described units, the Districts have installed nine other vortex flow pumps as shown in the following table. These pumps are installed in the most severe conditions in the Districts' system and to date have operated with little or no trouble due to clogging. It is the opinion of the Districts' engineers that the saving in maintenance labor and virtual elimination of down time more than offset the higher power costs caused by the somewhat lower pump efficiencies and the greater initial purchase price.

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Respectfully submitted,

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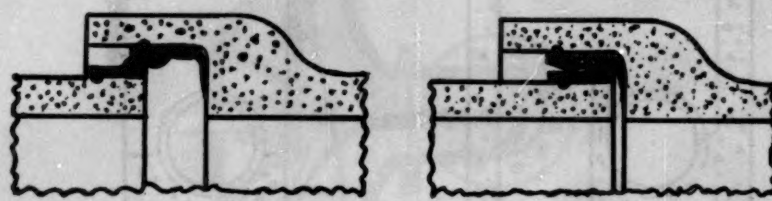
County Sanitation Districts
of Los Angeles County
Data for Recessed-Impeller, Vortex-Type Pumps

Location	No. of Units	Duty	Pump Size	Conditions GPM	Head	HP	Eff.	Pump Speed RPM	Date Put in Service	Remarks
Joint Disposal Plant W. Sludge Pump House	1	Raw sludge & skimmings	6"	600	20'	10	30%	520	Dec. 1953	No interruptions in service due to clogging to date.
Joint Disposal Plant So. Sludge Pump House	1	Digested Sludge	6"	600	78'	40	29.5%	1000	Sept. 1954	No interruptions in service due to clogging to date
Grape St. Pump Station	1	Unscreened Domestic Sewage	4"	350	18'	5	32%	660	Sept. 1954	No interruptions in service due to clogging to date
Joint Disposal Plant W. Sludge Pump House	1	Digested Sludge	6"	1400	43'	40	38%	825	July 1955	No service interruptions to date due to clogging
Lancaster Treatment Plant	1	Sludge Circulation and heating	4"	100	54'	10	13.6%	1040	Oct. 1955	No interruptions in service due to clogging to date
Joint Disposal Plant Adjacent to Digesters	2	Sludge Circulation and heating	6"	400	40'	15	27%	710	Nov. 1955	No interruptions in service due to clogging to date
Joint Disposal Plant Sludge Pump Station No. 1	3	Raw sludge	6"	500	52'	25	26%	825	Nov. 1955	No interruptions in service due to clogging to date
Hollywood Riviera Pump Station	2	Domestic Sewage	4"	525	32'	13	32.5%	900	--	Pumps to be installed early in 1956

General Data:

4" pump performance data shows best efficiency of 36% when operating at 1100 rpm delivering 560 gpm at 50 ft. Shut-off head at maximum speed of 1500 rpm is 117 ft.

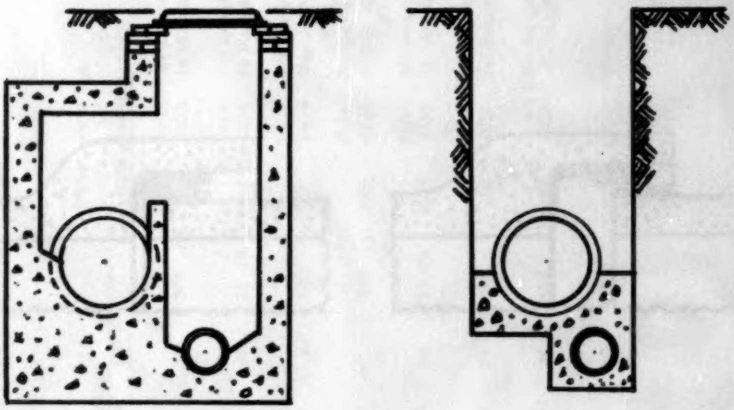
6" pump performance data shows best efficiency of 40% when operating at 800 rpm delivering 1100 gpm at 43 ft. Shut-off head at maximum speed of 1200 rpm is 118 ft.



Polyvinyl Chloride Gasket Joint

Section on left shows joint before being forced into compression. Soap solution lubricates polyvinyl chloride gasket to insure easy assembly. Joint on right shows how compressed gasket minimizes infiltration, exfiltration, and root penetration.

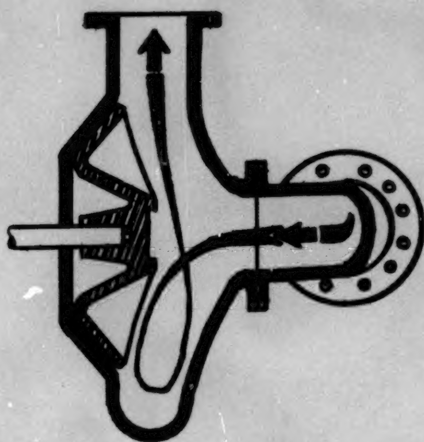
Figure 1



Twin Sewer Manhole Twin Sewer Construction

Vancouver practice combines storm sewers and sanitary sewers in one trench for two-thirds of the cost for separate trenches.

Figure 2



Schematic Section Thru Non-clogging Vortex-Flow Sludge or Sewage Pump

Recessed impeller is mounted completely out of the flow path between pump inlet and discharge outlet. Solids equivalent to discharge pipe diameter may be passed without difficulty.

Figure 3

Schematic Section Thru Non-clogging Vortex Flow Sludge and Sewage Pump

Figure 3

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

SED RESEARCH REPORT NO. 7

ON **INVESTIGATION OF PLANNED REFUSE COLLECTION AND DISPOSAL**

BY **The Sanitary Engineering Research Committee Rubbish and Garbage Section**

From Research Data of **A. M. Rawn, Chief Engineer and General Manager, Los Angeles County Sanitation Districts**

Acknowledgment: **The Sanitary Engineering Division gratefully recognizes the generosity and professional courtesy of the author in making these research data and information available for analyses by the Rubbish and Garbage Section of the Research Committee.**

Synopsis: **The results of 7 years investigation to develop a planned refuse disposal program for the Los Angeles County Sanitation Districts are summarized and critically evaluated. Data concerning different systems of refuse collection and disposal, including engineering factors for successful economical operation, are reviewed.**

INTRODUCTION

In large metropolitan communities adequate long-range refuse disposal programs are most important. The large volume of waste materials produced involves the expenditure of considerable monies and entails engineering problems of considerable magnitude to minimize nuisances and prevent offense to esthetic values.

The air pollution caused by burning in refuse incinerators has been the subject of investigation by the Air Pollution Control District of Los Angeles County; Stanford Research Institute; Batelle Memorial Institute, Columbus,

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Ohio; and the Air Pollution Foundation, Los Angeles. Studies have clearly established that backyard incinerators and other singlechamber burners discharge unreasonably large quantities of solid particulate matter and incompletely burned gases to the atmosphere. Based on this proof of the pollutional effects of inadequate incineration, it has been necessary to develop careful plans to minimize air pollution by either improving incineration techniques or by use of alternative refuse disposal systems such as sanitary landfill.

Classification of Refuse

The varying sources of supply of refuse result from the multiple activities of a large community. The most general classifications are garbage, comprised largely of table scraps; rubbish, including cans and bottles; and combustible rubbish, which includes varied items such as grass cuttings, shrub trimmings, paper and cardboard wastes, cloth and other similar materials. The origin of the refuse materials varies from homes, institutions, manufacturing plants, parks, and streets. A convenient tabulation of classifications of refuse is presented in Table 1.

Factors Affecting Collection

Factors such as the point of pick-up, the collection frequency, and the size of the collection crew directly determine the cost for equipment and manpower in a collection system; other indirect considerations such as climate, topography, and population density are significant in determining refuse collection costs and prevent direct comparison of cost data from one community with that of another.

The backyard pick-up of refuse in neighborhoods lacking alleys is about 40% to 60% more expensive than curb pick-up because backyard collection requires that the collection crew enter the home owners' property. Loading operation costs can be minimized through standardization of refuse containers. It is obvious that collection costs increase as time required for travel to disposal site increases; hence, refuse collection vehicles are generally inefficient for haul distances greater than 5 or 6 miles and for distances greater than 10 miles, it is almost always economically desirable to transfer refuse to a large-volume vehicle.

The costs for refuse collection obviously increase with the frequency of collection. A University of California study[1] indicates that two per week collection costs about 1 1/2 times as much as one per week collection. Since the incubation of the common house fly requires approximately 10 days, weekly collection of wrapped garbage and other refuse need not be a sanitary problem. Incentive pay systems such as reimbursement of a collection crew on the basis of a flat rate per route of service has been employed in some communities to reduce collection costs. Collection vehicles operate less efficiently in hilly terrain because of the reduced vehicle speed and increased cost for operating and maintaining the collection service in a low density population, mountainous district. Manpower requirements for refuse pick-up do not vary more than 5% for population densities ranging from 25 to 180

1. "An Analysis of Refuse Collection and Sanitary Landfill Disposal," Technical Bulletin No. 8, Sanitary Engineering Research Project, University of California (December 1952).

services per mile, while a service density of 10 services per mile requires about 1 1/2 times as much manpower as a service density of 40 or more services per mile. It is estimated that almost one-third of the homes in Los Angeles County utilize kitchen garbage grinders. More expense is entailed by the householder to dispose of garbage in this manner; however, householders enjoy the superior conveniences of this type of disposal.

Experience in refuse collection indicates that optimum type and capacity of refuse containers should be a standard 32 to 40 gallon metal container with tight-fitting lid for combined refuse or rubbish collection. A 10 to 12 gallon metal container with tight-fitting lid appears optimum for garbage when stored and collected separately. A maximum gross weight of 60 pounds is generally placed on refuse containers. Tree trimmings may be collected in bundles generally limited to overall dimensions of 4 feet in length and 12 inches in diameter.

Survey of Relative Costs for Refuse Collection

Questionnaires were sent to 90 cities and at least partial information was obtained from 50 of them. It was indicated that the curb pick-up was approximately 40% to 60% less than the cost of backyard pick-up. Tabulation of relative costs to a city for curb collection of different combinations of refuse are presented in Table 2.

The Nature and Quantity of Refuse

The quantity and nature of collected refuse are dependent upon such variables as climate, characteristics of residential area, individual lot sizes, type of landscape and the general standard of living of the residents. Data from Los Angeles and Long Beach, California, indicate that garbage production reaches a peak during the summer season, usually in July. Peak rates of garbage production generally do not exceed 100% of the yearly average refuse generation. The holiday seasons, particularly the Christmas and New Year holidays produce, as expected, larger quantities of rubbish. The quantities of refuse produced and collected in the Los Angeles County Sanitation Districts is presented in Table 3. This information, although not directly applicable to other areas of the United States, is indicative of the type of data that it would be desirable to obtain in establishing a planned refuse disposal system.

It is estimated that 30% by weight of the combustible refuse collected in Los Angeles is paper products. Paper products are consumed in the Los Angeles area at approximately 1.1 pounds per capita per day. It was estimated that the paper products salvage industry currently collects about 0.18 pounds per capita per day of fiber board (cardboard) and, in addition, about 0.25 pounds per capita per day of newspaper salvage, principally from residential sources. The commercial establishments salvage 0.25 pounds of fiber products per day; hence, it is indicated that approximately 2 pounds per capita per day of combustible rubbish is subject to routine collection. It is expected that the quantity of combustible rubbish will increase at approximately 1% per year until the year 2000. Noncombustible rubbish is produced in quantities of about 0.55 pounds per capita per day. Garbage, collected at the rate of about 0.48 pounds per capita daily, is cooked and fed to swine.

It is estimated that Park Department refuse amounts to 0.05 to 0.2 pounds per capita per day; Street Department refuse, 0.1 to 0.3 pounds per capita per day; discarded automobiles and large appliances and furniture, 0.1 to 0.15 pounds per capita per day; and solid industrial waste, disposed of to public facilities, 0.02 to 0.4 pounds per capita per day.

Refuse Disposal Processes

Numerous refuse disposal processes are used or have been proposed for use. These include garbage ground to the sewer, fed to hogs, or composted. Combustible refuse may be incinerated, salvaged, or buried in landfills. Non-combustible refuse is usually salvaged or landfilled. It has been proposed to compost organic refuse or possibly discharge it ground to sewers. The costs of refuse disposal are pertinent to the system to be employed. Landfill has proven to be an economical system for such refuse disposal and has, therefore, achieved great popularity. A typical cost comparison for various refuse disposal systems is illustrated in Fig. 1. These costs, excluding the cost of collection haul or revenue from sale of end products, vary from an estimate of \$0.30 for transfer of refuse, \$1 per ton for landfill disposal, through \$7 per ton estimate for composting costs.

Landfill Disposal

The feasibility of landfill disposal has resulted in the adapting of conventional sanitary landfill and cut-and-cover operation to use at special sites such as quarries and marshes. In California, canyon fills have been developed which employ the continuous placing and compacting of the sloping layers of refuse in depths of 4 to 20 feet. It has been found good practice to cover the sloped working face of the fill each day. There are at present 6 canyon landfills in the Los Angeles area; one of the most noteworthy examples is the Burbank, California, municipal landfill. A relatively flat bottom grade for the canyon is desirable. The soil type available for cover determines the cost of excavation, hauling, spreading and compacting. The general experience has been that existing fills with an exposed slope of 2:1 are acceptable. Investigations at Burbank indicate that the tangled nature of the compacted refuse results in high shear resistance. Usually each canyon site is filled from the head of the canyon and operations worked toward the mouth of the canyon. A bulldozer or crawler tractor with a shovel attached is economical for transporting fill up to distances of 300 to 400 feet. A carryall scraper is more economical for cover material for distances of 500 to 1000 feet.

Canyons with well-consolidated sedimentary deposits or igneous or metamorphic formations of solid rock should be avoided because of the difficulty in obtaining a fine grain soil for adequate cover and compaction of the refuse. A workable criterion is that there should be available at least 25% of the proposed fill volume as cover material.

Careful drainage is necessary to prevent rainfall washout of the canyon landfill. Canyons having considerable runoff may require diversion ditches along the side, at the head of, and possibly at the bottom of the fill.

In the City of San Diego, it was found that adjustment of moisture content by means of spraying the refuse with water resulted in improved compaction so that, whereas, unsprayed refuse compacted only 25% of its volume at the

disposal site, the compaction of the water-sprayed refuse was increased to 50%, enabling 50% additional disposal at the landfill site.

Tests performed at the City of Richmond, Virginia, landfill which has been operated since 1947, indicated that refuse placed in layers ranging from 6 feet to 15 feet deep in swamp waste lands, provides settlement of 5% to 10% within 5 years.

Landfills covered with 2 or 3 feet of well-compacted fill soil have been used for low-cost housing projects at Dallas, Texas; airfields at New York and Meriden, Connecticut; raising of alfalfa at Kerney, Nebraska; as well as normal use of landfill areas for recreational and parking areas. If it is desirable to pave a landfill area, a flexible paving should be used because of the settling that may occur.

Transfer and Haul

The use of transfer and haul is proving to be an economical and growing part of refuse collection systems. Improved vehicle designs have reduced the cost of such transfer and haul operations. At Chicago, 66 cubic yard capacity semi-trailers have been developed to transfer refuse to landfill disposal sites. These Chicago transfer vehicles have an endless belt type of moving floor unloader which completely unloads the 66 cubic yard trailer in about 5 minutes. It has been found by designers of both garbage and rubbish transfer vehicles that the conveniences of the tractor-semi-trailer combination is the most practical design, even though the maximum volume is less than that for a truck-trailer combination.

Transfer stations have been improved in design so that there is a maximum efficiency and minimum cost for the transfer of the refuse into the transfer vehicle.

Representative costs for refuse transfer and optimum zone radii for a typical transfer haul system are indicated in Figs. 2 and 3.

Incineration

The improvement of stack discharges from municipal incinerators is important in order to enable the satisfactory use of incineration in communities where air pollution control is a major problem. At Milwaukee, Wisconsin, the use of internal baffling and water sprays has enabled the Milwaukee incinerator to maintain stack discharge quality of less than 0.85 pounds of fly ash per 1000 pounds of flue gases (reduced to standard temperature and pressure). In some communities it has been difficult, and in other impossible, to obtain stack discharges which will meet local air pollution control standards.

Garbage Feeding to Hogs

Because trichinosis and a virus disease, vesicular exanthema, are transmitted principally through the feeding of uncooked garbage to hogs, it has been found desirable to heat treat collected garbage prior to its use as hog feed. Studies indicate that Los Angeles residential garbage can be properly heat treated and remain as good or better feed than raw garbage; hogs will

eat such heat treated garbage. The costs of heat treatment by means of injecting live steam to maintain boiling temperatures for 30 minutes is approximately $0.80 per ton. The cost of collecting garbage separately compared to mixed collection of rubbish and garbage demonstrates that the economic benefit to a community of hog feeding of garbage is negative; the community subsidizes hog feeding. The wholesale price of dressed garbage-fed pork in the Los Angeles area averages some $0.03 per pound lower than imported hogs from the midwest, while the additional increment for separate garbage collection over combined refuse collection represents approximately twice this amount, or a loss of about some $600,000 per year for the Los Angeles area.

Garbage Grinding

Ground garbage studies at Ohio State University and at the Sanitation Districts indicate that the home garbage disposal unit increases water usage between 1 and 2 gallons per capita per day. Central garbage grinding stations for discharge of the collected garbage into main sewers are operated in St. Louis, Richmond, Indiana, and other cities. Experience indicates that garbage may be introduced into the sewer at a maximum proportion of 2 tons of wet garbage per hour for each cubic foot per second of sewage flow. At this rate, the quantity of solids from the garbage in a sewer equals about 3600 ppm by weight and the sewage flow is still 99.6% water. A dilution water system capacity of about 15 gpm should be provided for each ton of garbage grinding capacity. Separation of cans and other inert solids are required before the grinding to the sewer.

Salvage of Non-Combustibles

The salvage of non-combustible refuse (cans, bottles, etc.) as a result of separate collection indicates that the community subsidizes this type salvage at a cost of approximately $2 per ton in comparison to combined collection.

Composting

Simple methods of composting utilizing windrows or stacks requires considerable land area. Mechanized composters such as silo-type installation have been experimented with at Michigan State College. The difficulty of operating the silo-type digester has resulted in a horizontal mechanical composter which employs 2 horizontal, non-continuous, Archimedes screws for continuously agitating ground garbage and moving it from the end of the composters to the discharge point at the other end. The mechanical difficulties appear to be reduced over the vertical silo device and satisfactory composting is achieved in about two or three days. The cost of mechanical composting is estimated at about $7 per ton of garbage-rubbish. The problem of disposing of the finished product to a local market remains as a challenge before there can be successful future application of composting systems.

Grinding Rubbish to Sewers

Los Angeles County Sanitation Districts investigations indicate the feasibility of grinding rubbish to the sewer at the approximate cost of $1.10 per

ton. The grinding of all garbage and combustible rubbish to a sewer system would increase the total solids loading about 500 % or the total cellulose load by about 800%. Batch tests carried out in 55-gallon drums indicate that a 1" screen opening for the ground refuse will insure against problems in the sewer and removal systems; however, the digestion and decomposition of refuse is not deemed rapid enough, even with grinding through a 1/2" screen. Additional study of the optimum peak size for ground refuse appears necessary. It is estimated that it would cost approximately $0.75 per ton for collection and separate digestion of the ground refuse at a primary treatment plant increasing the estimate of cost for disposal by this method to about $1.85 per ton.

Summary and Conclusions

Investigation of a planned refuse disposal program for Los Angeles County Sanitation Districts has developed certain general conclusions that are reviewed as follows:

1) Once a week collection of mixed refuse is the most economical over-all collection system. Separate collection of garbage, combustible and non-combustible rubbish is more costly than combined collection, even though hog feeding and monetary returns from salvage are considered.
2) Refuse transfer and haul systems enable the economical employment of landfills in relatively remote areas. Improved transfer station design and large transfer truck vehicles may provide a lower cost refuse disposal system than alternate methods under most operating conditions.
3) Possibilities of utilizing water conveyance in sewers for the transportation of ground refuse to a treatment works appear encouraging for future development.
4) Numerous aspects for collection and disposal of refuse are <u>carefully</u> reviewed and analysed in connection with their pertinent operating and cost characteristics. This fund of data is summarized in the report discussion.
5) Additional research of sanitary landfill, incineration, and other components of the refuse disposal system are needed for further development of the refuse disposal field.
6) Over a 7-year period diverse information concerning refuse collection and disposal has been carefully compiled and developed for application to a planned refuse disposal program for Los Angeles County. This information, although not all of it directly applicable to other municipalities, has much fundamental data that should be of interest to the engineering profession.

Credit

This research report is one of a series of professional contributions by the Committee on Sanitary Engineering Research,

William T. Ingram	Air Pollution
Herman R. Amberg	Stream Pollution
Jess C. Dietz	Sewage
Marvin L. Granstrom	Water

E. R. Hendrickson	Public Health
Ralph Stone	Rubbish and Garbage
Chairman, Nelson L. Nemerow	Industrial Wastes

The report has been prepared by the Rubbish and Garbage Section:

F. R. Bowerman
Ralph Stone, Chairman

TABLE 1

CLASSIFICATION OF REFUSE

Classification			*Description*	*Origin*
Refuse subject to routine collection	Garbage		Wastes from the preparation, cooking, and consumption of food. Food wastes from produce markets and food processing establishments.	From homes, hotels, institutions, stores, markets, etc.
	Rubbish	Combustible rubbish	Paper, fiberboard (cardboard), wood, excelsior, tree and yard trimmings, grass, rags, rubber, and plastics.	
		Non-combustible rubbish	"Tin" cans, scrap metal, bottles, glass, crockery, ceramics, ashes, and other mineral refuse.	
Refuse not subject to routine collection	Refuse from Residences		Large discarded appliances, bed springs, logs, stumps, rubble, construction waste, dirt, junked automobiles, dead animals.	From homes.
	Refuse from Municipal Functions		Street sweepings, park refuse, catch basin dirt, paving, rubble, dirt, construction wastes, dead animals.	From streets, sidewalks, alleys, vacant lots, parks, etc.
	Refuse from Industry		Solid waste resulting from industrial processes and manufacturing operations.	From manufacturing and processing plants.

TABLE 2

RELATIVE COSTS TO CITY "A" FOR CURB COLLECTION

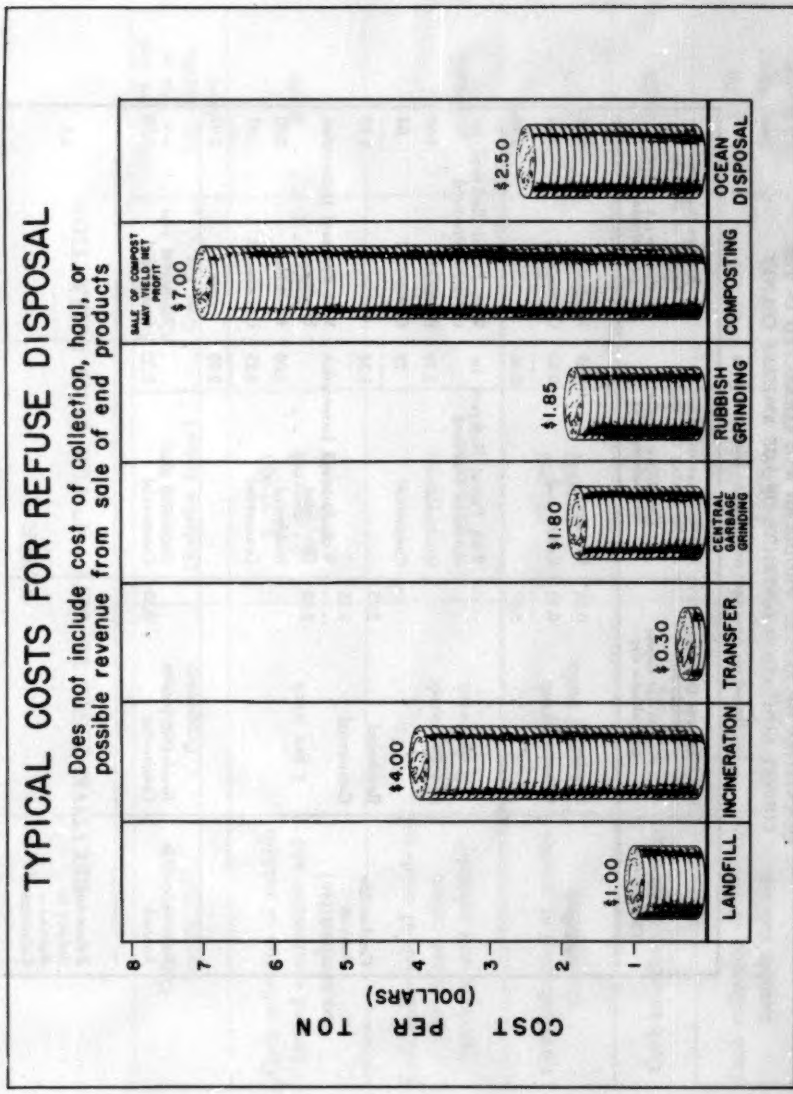
Collection Service	Collection Frequency	Annual Cost (Relative Index)	Calculated Collection Cost Per Ton	Observed Cost per Ton in Los Angeles Area
Curb collection of rubbish (mixed combustible and non-combustible)	1 per week	$100,000 (assumed unit cost)	$6.00	$6.00
Curb collection of combined or mixed refuse (garbage and rubbish)	1 per week 2 per week	$118,000 $176,000	$6.00 $8.00	not practiced
Curb collection of combustible rubbish	1 per week 1 per 2 weeks	$95,000 $82,000	$7.25 $6.00	$6.75
Curb collection of garbage	2 per week	$33,000	$10.50	$9.00
Curb collection of non-combustible rubbish	1 per week 1 per 2 weeks	$33,000 $29,000	$10.25 $9.50	$6.50 once every 3 weeks

TABLE 3

QUANTITIES OF REFUSE PRODUCED AND COLLECTED IN THE COUNTY SANITATION DISTRICTS OF LOS ANGELES COUNTY

Based on Averages over Entire Districts Area

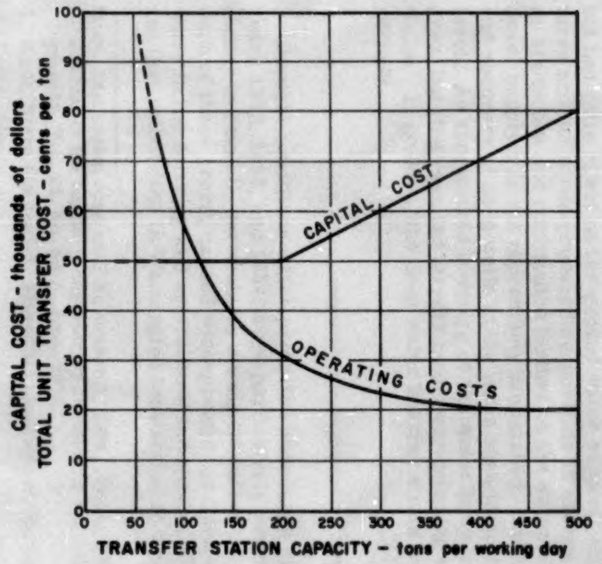
Refuse Classification	Average Quantity Produced — Pounds per Capita per calendar day		Average Quantity Now Being Collected — Pounds per Capita per calendar day		Average Quantity Subject to Disposal — Pounds per Capita per calendar day	
Garbage	Residential	0.55	Residential	0.38	Residential	0.38
	Commercial	0.12	Commercial	0.10	Commercial	0.10
		0.67		0.48		0.48
Combustible Rubbish			With Partial Backyard Incineration Practiced		With Partial Backyard Incineration Practiced	
			Residential	1.10	Residential	1.06
			Commercial	.22	Commercial	.04
	Residential	2.25		1.32		1.10
	Commercial	0.25	With Backyard Incineration Eliminated		With Backyard Incineration Eliminated	
		2.50	Residential	2.00	Residential	2.00
			Commercial	0.25	Commercial	.07
				2.25		2.07
Non-combustible Rubbish	Residential plus Commercial	0.55	Residential plus Commercial	0.50	Residential plus Commercial	0.50
Refuse *not Subject to Routine Collection*						0.5



SEPT. 1955

FIG. 1

FIG. 2

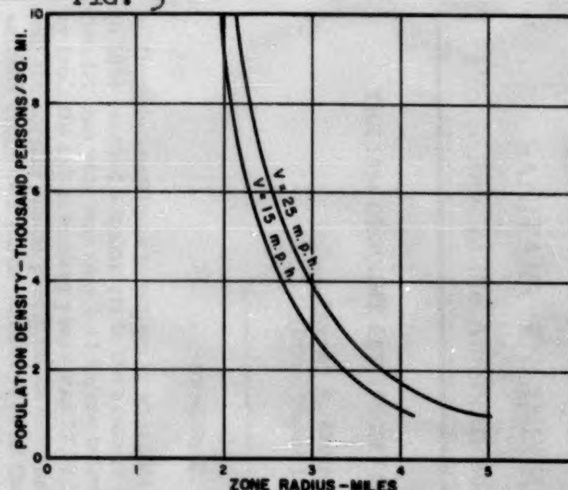


REFUSE TRANSFER COSTS

Figure 2. Capital Costs of Transfer Stations and Total Operating Costs are Shown as Functions of Station Capacity for Earthfill Construction, Direct-Dump, Single-Shift Stations

Operating costs include labor, maintenance, utilities and amortization of all capital costs at 3% interest. Costs for stations larger than 500 tons per working day cannot be generalized; however, operating costs will seldom be less than $0.20 per ton.

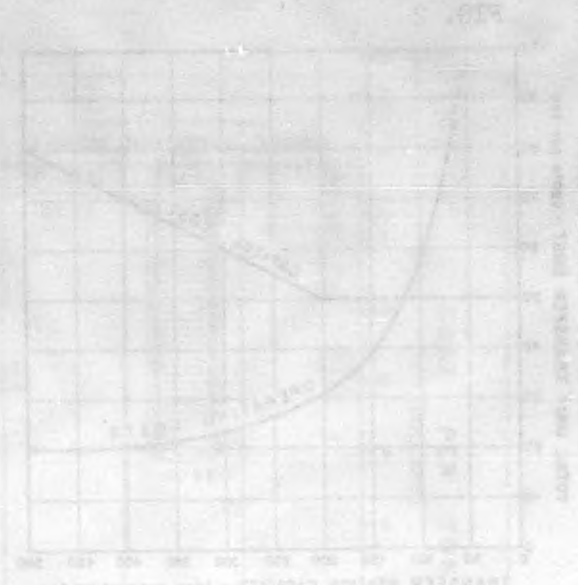
FIG. 3



OPTIMUM COLLECTION ZONE RADII
FOR TYPICAL TRANSFER-HAUL SYSTEM

Figure 3. Collection Zone or "Transfer Area" Radii for Minimum Collection Cost are shown as a function of Population Density and Average Collection Vehicle Haul Speed

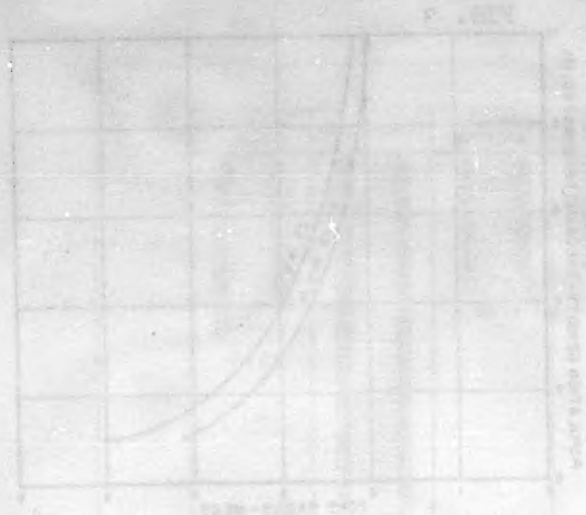
Analysis is for a typical municipally operated refuse collection system using mechanical compaction collection vehicles with 3-man crews. Collection of 3.2 pounds per capita per day of combined refuse and a 6 day work week have been assumed.



REFUSE TRANSFER COSTS

Figure 7. Capital Costs of Transfer Stations and Total Operating Costs are Shown as Functions of Station Capacity for Band (?) Construction, Direct-Dump, Single-Shaft Stations

Operating costs include labor, maintenance, utilities and amortization of all capital costs at 3½ percent. Costs for stations larger than 800 tons per working day cannot be generalized. However, operating costs will seldom be less than $0.50 per ton.



OPTIMUM COLLECTION ZONE RADII FOR TYPICAL TRANSFER-HAUL SYSTEM

Figure 8. Collection-Zone-to-"Transfer Area" Radii for Minimum Collection Cost are shown as a Function of Population Density and Average Collection Vehicle Haul Speed

Analysis is for a typical municipally operated refuse collection system, using conventional compaction collection vehicle with 3-man crews. Collection of 6.2 pounds per capita per day of combined refuse and a 5 day work week have been assumed.

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THE 1954 DROUGHT AND ITS EFFECT ON GROUND WATER

Garrett A. Muilenburg[1]
(Proc. Paper 1016)

SYNOPSIS

Drought conditions prevalent in Missouri and neighboring areas from 1952 to 1954 reached a maximum in the summer of 1954. Although the precipitation for that year was only 5.13 inches below normal, the cumulative deficiency from the two preceding years was 22.77 inches. This is more than one-half the normal annual precipitation and was largely responsible for the disastrous conditions which marked 1954 as the worst in history. Ground water in the shallow zone was below normal throughout the three-year period, and many wells became dry and stream and spring flow was greatly reduced or failed entirely. Normal rainfall late in 1954 restored surface soil moisture, but had little effect on the ground water supply. Abnormally high temperatures and hot winds produced evaporation in excess of the normal by as much as six inches and contributed further to the water shortage. The deep ground water supply was not appreciably diminished. Records of pumpage, drawdown, and recovery of deep wells in the Rolla area indicate no lowering of the water level. An appreciable lowering of the water table took place in the Springfield area, but this resulted largely from over-pumping and too close spacing of wells. In general, the deep water bearing strata were not affected by the drought.

Drought conditions which prevailed over large parts of the country in the years 1952, 1953, and 1954, were particularly severe in Missouri. The deficiency in rainfall, particularly during the latter part of the growing season of each of these years, caused widespread crop failure and spelled disaster for many in the dairying and agricultural industries. The situation was so critical that authorities in Washington took action to bring relief by making

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available funds to purchase hay and other feed in areas where there was a surplus and shipping it into the needy areas. Railroads serving those areas cooperated by reducing freight rates for the emergency and making available other facilities to help relieve the distress.

The seriousness of the widespread and recurring drought conditions caused much speculation among people of all classes and professions as to the causes and as to what the future might hold in store. Some of the more extreme even visualized desert conditions in the Mississippi Valley. Needless to say, such alarm was not justified in the light of our knowledge of geologic and climatic conditions.

A study of the situation naturally brings up the question, "What causes a drought?". The answer is not simple and cannot be expressed in a few words. It involves many factors, some of which are quite evident and others which are less obvious. Among the more common causes of droughts are:

1) Deficiency of precipitation
2) Unfavorable distribution of precipitation
3) High temperatures
4) Hot winds
5) Low humidity
6) Excessive evaporation

These are all more or less dependent upon each other, but at least the first two can independently produce critical conditions. Droughts such as those of the recent years were probably caused by a combination of all of these factors with the addition of another less obvious cause: the cumulative effect of the drought-making conditions over several successive years. Drought effects in a single season are usually relieved by normal rainfall in the following season, but when drought conditions persist for several years, the cumulative effects are more severe and may be felt even in following years when rainfall is normal. Subsoil moisture, lost over a period of several years, cannot ordinarily be replaced in a single season.

Deficiencies in precipitation at selected localities in Missouri for 1952 to 1954 are shown in figure 1. With the exception of Tarkio, all stations reported below normal precipitation for each of the three years. The cumulative effect of the shortage in 1952 and 1953 resulted in more severe drought conditions in 1954, even though the total precipitation for that year was greater than for the preceding years. A further contributing cause to the 1954 drought was the unfavorable distribution of rainfall through the year. Figures 2, 3, and 4 show the annual distribution in the St. Louis area. Other localities may have differed somewhat, but in general, the pattern is similar. Favorable distribution of precipitation is perhaps of more vital importance than total quantity, because light rains at frequent intervals result in less run-off than in less frequent heavy rains.

Deficiency in precipitation in Missouri for the three years, 1952-1954, amounted to an average of 9.3 inches per year and made this the driest three-year period in the climatological history of the state. Attention has already been directed to the fact that although in 1954 the actual deviation from normal precipitation was only 5.13 inches, it was insufficient to offset the cumulative deficiency of the preceding years, and 1954 went on record as the most disastrous drought in history.

The effect of temperature on drought is mostly indirect in that it causes more rapid evaporation. From 1952 to 1954, temperatures in this area were

unusually high; from June to September, the temperature in St. Louis was 4.6 degrees above normal. Outlying areas in the state showed similar or greater departures from the normal. Twenty-two days with temperatures above 100 degrees were recorded at Warsaw. High temperatures have a tendency to produce hot winds which contribute to the drought by increasing the evaporation from the surface of the land and by greater transpiration from vegetation. The capacity for rapid evaporation and increased transpiration is present whenever temperatures are high and humidity is low. Figure 5 shows the monthly evaporation in inches for the three drought years at the Washington University Weather Station in St. Louis. Data on departures from the normal are not available, but an estimate for 1954 indicates that evaporation losses exceeded the normal by five or six inches.

The effect of drought on ground water is influenced by several factors which determine the quantity and distribution of ground and surface water and their relations to each other. The relation between precipitation and surface water supply is readily observed because surface water is something tangible. The relation to ground water supplies cannot be readily evaluated because ground water supplies are intangible and depend in part on geologic conditions. Factors commonly considered as having a bearing on the ground water supply are climate, vegetation, topography, geology, total precipitation, rate of precipitation, condition of the surface, and perhaps others less readily recognized. In other words, the relation between droughts and water supplies and the effect upon growing crops is governed by the basic principles of hydrology.

When water falls on the surface as rain, a part of it is immediately evaporated and returned to the atmosphere, the quantity depending upon climate, temperature, geographic situation, and other factors. A part of it accumulates on the surface in lakes, ponds, and surface streams, and another part sinks into the ground to become part of the ground water system. The outer part of the earth, a belt ranging from a few feet in thickness in some places to several hundred feet in other places, acts as an intake or gathering zone. In times of plentiful rainfall, this zone is largely saturated, but soon loses some of its water content by evaporation, transpiration, and by seepage into the lower zone of saturation. This lower zone is the zone of permanent ground water. Here, generally, water is under hydrostatic pressure and moves through the pore space in the rocks by gravity, aided by pressure.

Water in the zone of saturation is generally too deep to be used directly by vegetation, but is a source of supply for domestic and other uses. Growing crops generally obtain their needed moisture from the upper gathering zone. Therefore, vegetation shows the effect of a drought even before water supplies from wells are affected.

During dry periods, wells which penetrate only into the outer zone often go dry. Hillside or wet weather springs and seeps dry up because they are above the zone of saturation. Shallow wells and springs which penetrate into the zone of saturation will continue to yield water, but the flow is likely to be greatly diminished. During the recent droughts, many wells failed and springs either dried up or were reduced to mere trickles. Only those wells which penetrated into the deeper strata where the water is under hydrostatic pressure continued to yield a steady supply. The water supply in these deeper strata is not subject to seasonal fluctuation nor is it affected by local precipitation. Ideally, such water-bearing strata are porous, permeable rock, in many cases sandstone, through which water is free to move by gravity and under pressure. The water generally comes from distant sources of intake.

An impervious cap rock over the water-bearing stratum is essential. Because the area of intake may be at a considerable distance and because the rate of movement is slow, excesses or deficiencies in precipitation are not generally recognizable. The effect of a drought, even of several years duration, may become equalized and obliterated in the great reservoir of ground water by lateral movement long before it would ever become apparent in wells penetrating the water-bearing stratum. For instance, the water supply at Rolla, and over most of the Ozarks, is obtained from depths of a thousand feet or more from rock formations exposed at the surface in the St. Francois Mountain area, 50 to 75 miles away. It may be as much as 100 years before water falling as rain on the surface reaches the vicinity of Rolla, and may be 200 years or more before it reaches Springfield. Therefore, the effect of a dry season or an excessively wet season would not be recognizable.

Although comparatively few actual records are available, experience over the last three years indicates no appreciable lowering of the static water level in deep wells where they are spaced far enough apart to prevent interference. In Springfield, there has been an appreciable lowering of the water level, but it seems to be entirely the result of over pumpage from numerous wells so closely spaced that there is considerable interference. In Rolla, under more or less ideal conditions of spacing and a regular schedule of pumping, no lowering of the static water level or increased drawdown has been detected even though the consumption was very high during the hot, dry weather.

In wells which do not penetrate to the major water-bearing horizons in the Rolla area, for instance wells bottomed in the Roubidoux formation, an appreciable lowering of the water level is apparent. The water in these wells comes from local sources of intake, and the supply is, therefore, affected by seasonal and annual fluctuation in rainfall.

Figure 6 is a record of the water level in an observation well at the Geological Survey Building at Rolla, bottomed in the Roubidoux sandstone. There is apparent relation between precipitation and the static water level, although there is a slight lag before the effect of increased rainfall is noticeable.

Wells which obtain water from the surface soil or from alluvium along streams show the effect of droughts to an extent which is commensurate with the area available as a source of supply and with the lithologic nature of the soil and alluvium. Residual clay soil has little water carrying capacity and wells in that type of material produce little water, and fail at the first sign of dry weather. Wells in sand and gravel on large alluvial bottoms usually produce an abundance of water with little or no lowering of the water level. Exceptions, of course, are to be noted where wells interfere because of close spacing and where they are pumped excessively. In the southeast Missouri lowlands such wells are used for irrigation and heavy pumping has depressed water levels temporarily, but the water rises again by natural re-charge when rainfall is more abundant.

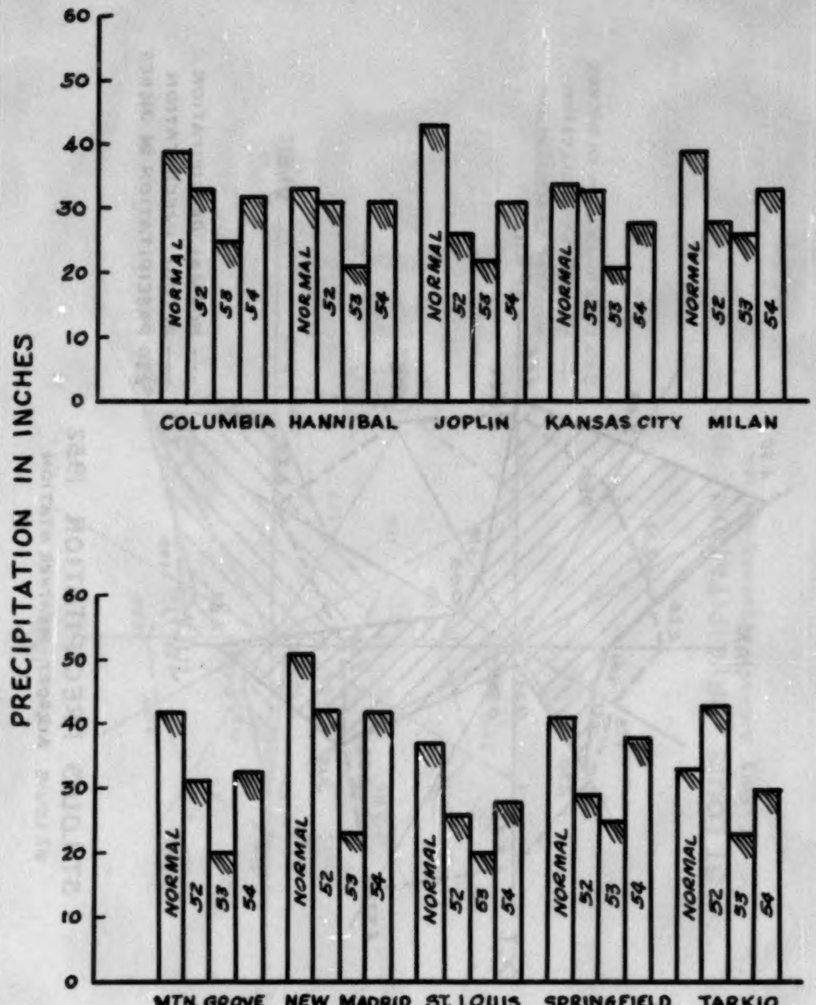
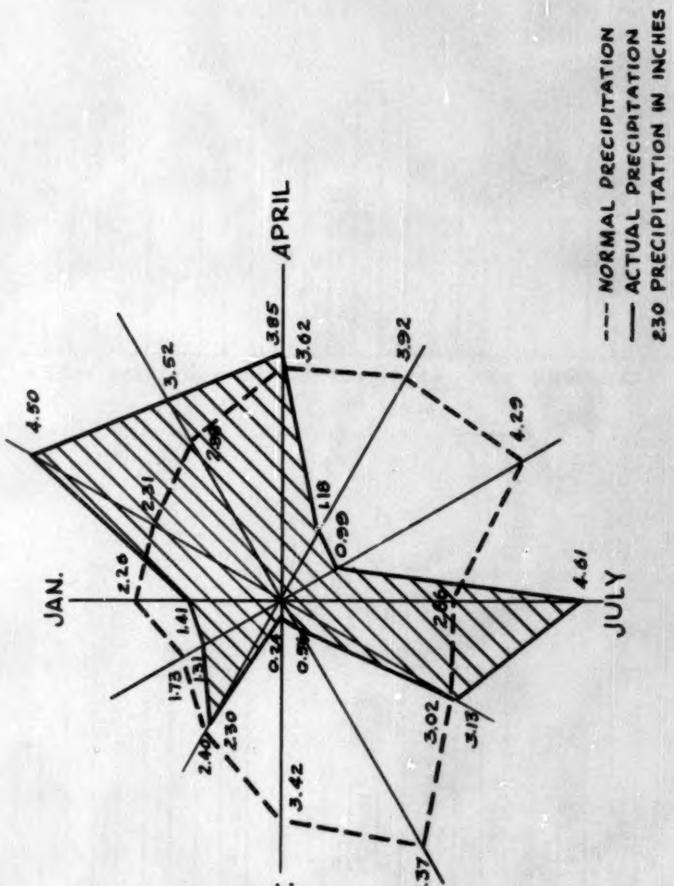


FIG. 1 TOTAL PRECIPITATION & DEVIATION FROM NORMAL



ST. LOUIS PRECIPITATION 1952
ST. LOUIS AIRPORT WEATHER STATION

FIG. 2

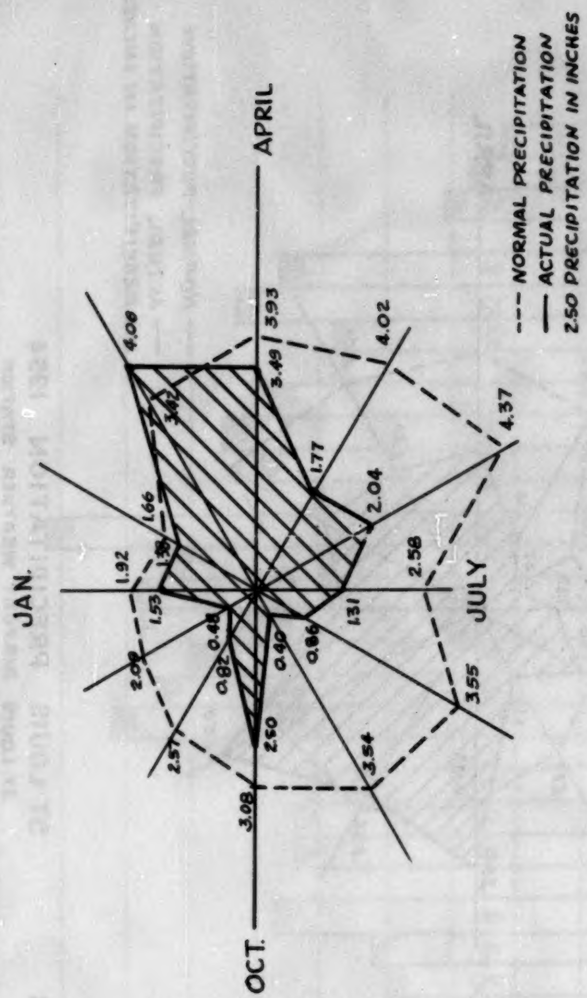


FIG.3 ST. LOUIS PRECIPITATION 1953
ST. LOUIS AIRPORT WEATHER STATION

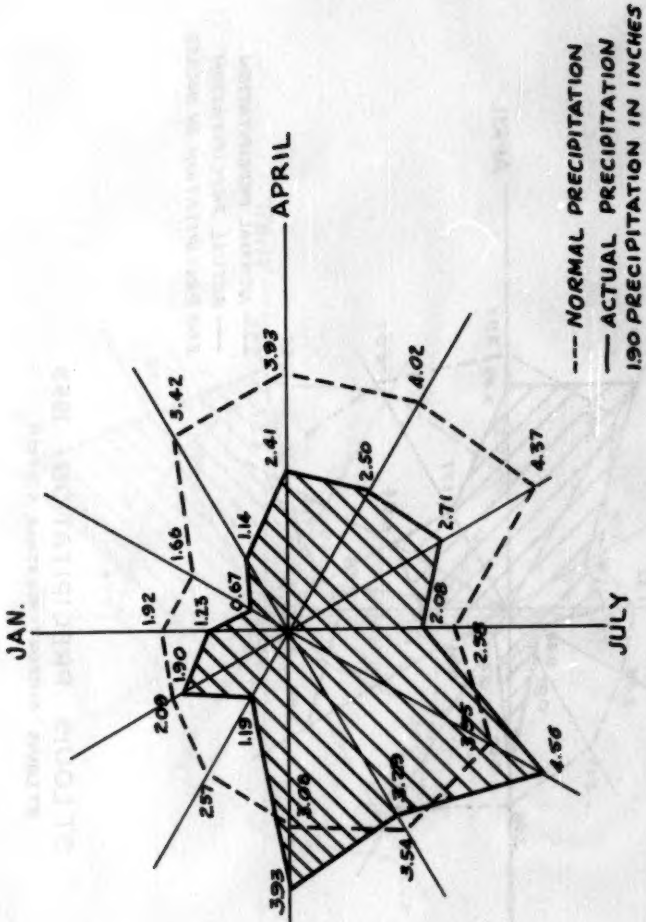


FIG. 4 ST. LOUIS PRECIPITATION 1954

ST. LOUIS AIRPORT WEATHER STATION

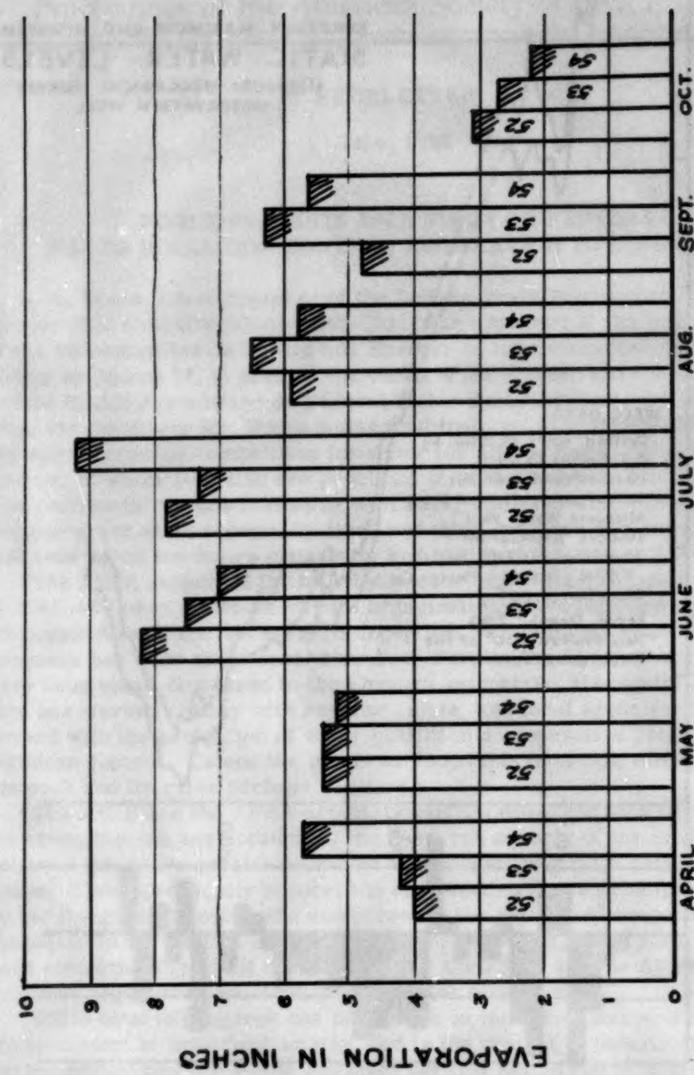
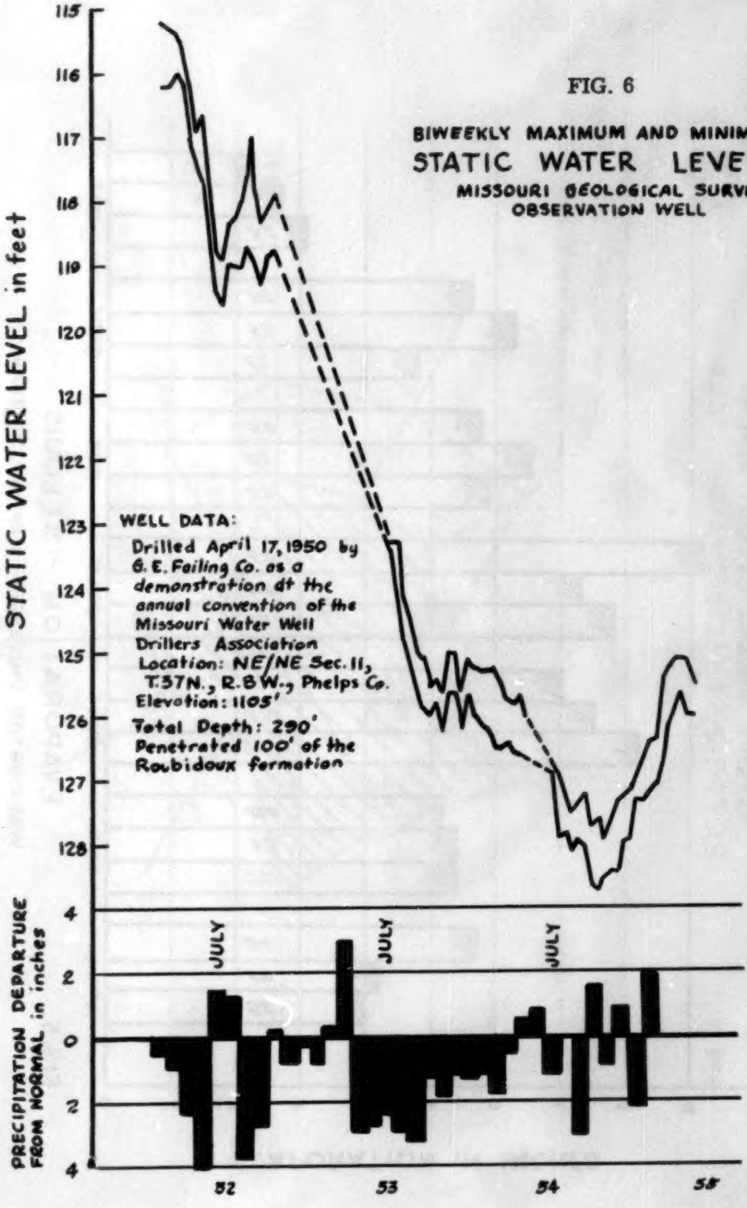


FIG.5 EVAPORATION – ST. LOUIS
WASHINGTON UNIVERSITY WEATHER STATION

FIG. 6


BIWEEKLY MAXIMUM AND MINIMUM
STATIC WATER LEVELS
MISSOURI GEOLOGICAL SURVEY
OBSERVATION WELL
STATIC WATER LEVEL in feet
115
116
117
118
119
120
121
122
123
124
125
126
127
128
WELL DATA:
Drilled April 17, 1950 by
G. E. Failing Co. as a
demonstration at the
annual convention of the
Missouri Water Well
Drillers Association
Location: NE/NE Sec. 11,
T.37N., R.8W., Phelps Co.
Elevation: 1105'
Total Depth: 290'
Penetrated 100' of the
Roubidoux formation
PRECIPITATION DEPARTURE FROM NORMAL in inches
4
2
0
2
4
JULY
JULY
JULY
52
53
54
55

DIVISION ACTIVITIES
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

NEWSLETTER

June, 1956

POOLE PRESENTS ASCE VIEWS ON FEDERAL WATER POLLUTION CONTROL LEGISLATION TO COMMITTEE

B. A. Poole, Chief Engineer of the Indiana State Board of Health and former SED Executive Committee Chairman appeared at the Public Hearings of the Subcommittee on Rivers and Harbors of the Committee on Public Works on March 13, to present the views of the Society and the American Public Health Association on Federal Water Pollution Control legislation.

In the statement Mr. Poole pointed out that . . . "Unprecedented demands for water, growing competition for water for all purposes, and increased sources of water pollution are problems of paramount concern to the Nation. How successful we are in dealing with water pollution which constitutes a serious drain on an essentially fixed and vital resource will have an important bearing on the future prosperity and health of the Nation."

"The ASCE supported the bill that became the Water Pollution Control Act of 1948 and many members of both organizations have followed closely the administration of the Act from its inception. We feel that much worthwhile progress has been made under this Act. Despite the fact that appropriations have been small compared to the amounts authorized, the Public Health Service has worked closely with regional, state, and local agencies that are concerned with the protection of water quality in a cooperative program of stream pollution control. Unless the Act is extended this program will be seriously set back and its gains perhaps nullified."

"The ASCE and the APHA are particularly impressed with the provision for strengthening and broadening the research aspects of the program. They believed that other provisions aimed at strengthening State programs are sound. They specifically support the continuation of the principle enunciated by the Congress to recognize and preserve the rights and responsibilities of the States in the control of water pollution. However, many state programs need strengthening and it is the opinion of the ASCE and the APHA that the proposed legislation would be helpful in that direction."

"While notable progress has been made in the construction of facilities for the treatment of municipal wastes, and in the control of industrial wastes during the period that the Water Pollution Control Act has been in effect, the

Note: No. 1956-14 is part of the copyrighted Journal of the Sanitary Engineering Division of the American Society of Civil Engineers, Vol. 82, SA 3, June, 1956.

problem as a whole has grown in magnitude during this period and presents an equal or greater challenge than it did eight years ago. We in the ASCE and the APHA are convinced that the solution of this still-growing problem will require the utmost cooperation among the States, the local communities, industry, the Federal Government, and the sanitary engineering and allied professions. We believe that the successful development of such a cooperative effort will make an invaluable contribution to the future progress of our country."

No report had been made by the Committee up to the time material was submitted for this issue of the SED Journal. It is anticipated, however, that a report will be made before publication of the Journal.

* * * * * * * * * * * * * * *

Mark your Calendar—ASCE Spring Convention—Jackson, Mississippi, February 18-22, 1957.

COMMITTEE NEWS

The COMMITTEE ON PREPARATION OF A MANUAL OF PRACTICE ON SANITARY AND STORM SEWER DESIGN will meet in New Orleans June 27-30 for a final review of the manual. A previous meeting was held on March 1-3 in Cincinnati during which complete reviews were made of each subject. Suggestions made for the improvement of the manual at this meeting will be incorporated into the final draft by subject chairman and this draft reviewed at the New Orleans Meeting.

* * * * * * * * * * * * * * *

A meeting of The COMMITTEE ON THE PREPARATION OF A MANUAL OF PRACTICE ON SEWAGE TREATMENT PLANT DESIGN will be held in Cleveland June 14-16 to review the first draft of the Manual. According to Prof. Daniel A. Okun, Chairman of the Committee first drafts of most of the chapters have now been submitted and work on the Manual is progressing. Chapters of the Manual and Committee Members responsible are as follows:

Chapter 1. Basic Design Consideration (Ordway, Klegerman, New York, N.Y.)
Chapter 2. General Plant Layout (Ordway, Klegerman, New York, N.Y.)
Chapter 3. Plant Pumping Stations (Caldwell, San Francisco, Calif.)
Chapter 4. Screening of Sewage (Erganian, Indianapolis, Ind.)
Chapter 5. Grit Removal (Erganian, Indianapolis, Ind.)
Chapter 6. Flotation Units (Okun, Chapel Hill, N. C.)
Chapter 7. Flocculation of Sewage (Caldwell, San Francisco, Calif.)
Chapter 8. Sedimentation Units (Wraight, Indianapolis, Ind.)
Chapter 9. Chemical Precipitation (Hubbell, Detroit, Michigan)
Chapter 10. Activated Sludge (Haseltine, Pittsburgh, Pa.)
Chapter 11. Trickling Filters (Erganian, Indianapolis, Ind.)
Chapter 12. Miscellaneous Aerobic Biological Treatment Units (as shown)
    12.1 General (Erganian)
    12.2 Intermittent Sand Filters (Van Kleeck)
    12.3 Oxidation Ponds (Caldwell)
Chapter 13. Sludge Pumping (Van Kleeck, Hartford, Conn.)
Chapter 14. Sludge Digestion (Van Kleeck, Hartford, Conn.)

Chapter 15. Sludge Dewatering and Disposal (Van Kleeck, Hartford, Conn.)
Chapter 16. Chlorination of Sewage (Hubbell, Detroit, Michigan)
Chapter 17. Chemicals (Okun, Chapel Hill, N.C.)
Chapter 18. Service Buildings (Ordway and Klegerman, New York, N. Y.)
Chapter 19. Miscellaneous Design Considerations (Ordway and Klegerman, New York, N. Y.)
Chapter 20. Materials and Construction Requirements (Martin, Green Bay, Wisconsin

SED Members having specific information they believe should be considered are urged to contact individual responsible for the specific subject.

* * * * * * * * *

The COMMITTEE ON WATER SUPPLY is actively working on its report and has established a publication schedule. Subcommittee Members and Schedule are reported by Chairman Robert D. Mitchell as follows:

Section I - WATER RESOURCES John D. Longwell George E. Ferguson Melvin P. Hatcher	Winter 1955-56
Section II - WATER E. A. Pearson Marshall Crabill Jack A. Borchardt	Spring 1958
Section III - DESIGN OF SUPPLY WORKS Karl Kennison N. J. Carlock Vacancy	Fall 1956
Section IV - DESIGN OF TREATMENT WORKS Inactive pending completion of work of Committee on Revision of Manual No. 19	Not scheduled
Section V - DISTRIBUTION SYSTEM Thomas Niles Vacancy Vacancy	Spring 1957
Section VI - FINANCING AND LEGAL Ernest W. Whitlock Vacancy Vacancy	Fall 1957
Section VII - SPECIALIZED SUBJECTS Robert Harris Ralph Palange Vacancy	Spring 1956

SED members desiring to make a contribution should contact Committee Members at an early date.

* * * * * * * * *

The COMMITTEE ON THE RUDOLPH HERING MEDAL AWARD has recommended to Roy J. Morton, Chairman of the Executive Committee that the award be made to Thomas R. Camp for his paper entitled "Flocculation and Flocculation Basins."

In the recommendation the Committee pointed out that the choice between this paper and "Stabilization of Municipal Refuse by Composting" by McGauhey & Gotaus was most difficult and recommended that the second paper be held for consideration with next year's papers.

Ross E. McKinney, Chairman, William W. Altman, and Nelson L. Nemerow are to be commended for the time and effort that they expended in behalf of the SED. This selection is always a difficult task when there are a number of excellent papers.

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CORRECTION - The list of members of the COMMITTEE ON PREPARATION OF A MANUAL OF PRACTICE ON SEWAGE TREATMENT PLANT DESIGN. The names of Norval E. Anderson, Clyde L. Palmer and David H. Caldwell were included through error and the names of Frank V. Wraight, George E. Hubbell, and Norman B. Hume were omitted. We apologize Gentlemen.

CERTIFICATION

Plans for the certification of Sanitary Engineers are progressing but at the time the newsletter was prepared the Board of Trustees were not ready to distribute application forms. It was hoped, however, that the development of the application form could be completed and distribution started in June 1956.

Until July 1, 1957 it will be possible to consider certification of certain qualified individuals without examination. After July 1, 1957 everyone certified will be required to take the examination as part of the accrediting procedure. Those applying for certification prior to July 1, 1957 who do not have the qualifications for certification without examination will be accepted for the examination as soon as necessary investigations can be made. It is not possible at this time to predict when the first examination can be scheduled.

The articles of incorporation and by laws of the American Sanitary Engineering Intersociety Board were published in the February 1956 issue of the newsletter. It is recommended that you review this material. If for some reason you did not receive your copy, a copy of the material can be obtained by writing to Francis B. Elder, Room 1601, 33 West 39th Street, New York 18, New York.

DID YOU KNOW THAT -

The Board of Directors of ASCE have adopted a policy and have asked the Technical Divisions to set up separate Committees for Publications and Programs since it was observed that manuscripts written informally for programs were not up to the standards required for the Divisions journal. This does not affect the SED for our Executive Committee had taken the initiative and made the separation prior to the action by the Board of Directors.

* * * * * * * * *

We want news items from Consulting Engineers, Manufacturers' Representatives, Industries, Universities, etc. We want this newsletter to reflect the activities of ALL Sanitary Engineers but we can't include news items unless you submit them. Surely there are items of news of interest to the membership generally in your daily activities. Why not send them to the Editor.

* * * * * * * *

The Public Health Service has prepared an inventory of municipal water facilities serving 10,000 people or more and a 40 percent sample of those serving between 5,000 and 10,000. The inventory was prepared under a delegation by the Office of Defense Mobilization as part of the Government's mobilization readiness planning activities. It lists, among other things, population served, source of supply, treatment provided, capacity, storage, and the improvements which local officials consider necessary to maintain satisfactory service.

* * * * * * * *

A summary of research grants in sanitary engineering approved by the Public Health Service between July 1 and December 31, 1956, has been released by the Public Health Service. Grants in the field of sanitary engineering are made on the recommendation of the Study Section on Sanitary Engineering and Occupational Health and are administered through the Division of Research Grants, National Institutes of Health.

A tabulation of these sanitary engineering research grants, made primarily to universities and other research institutions throughout the country, follows:

	No. of Grants		
	New	Continuing	Total
Water Pollution and treatment	10	14	$195,688
Sewage and industrial wastes	14	5	207,348
Community air pollution	7	5	322,480
Other sanitary engineering projects	5	2	86,920
Occupational health	3	2	63,978
	39	28	$876,414

Increased interest in sanitary engineering research grants is evidenced by the growing number of applications now being received by the Sanitary Engineering and Occupational Health Study Section. Further information on the 67 active grants, including the names of the investigators, institutions, and amounts of support, may be obtained.

* * * * * * * *

The Conference on Water Reclamation sponsored by the University of California held January 26 and 27 was attended by over 200 Sanitary Engineers. The Conference which was under the direction of Professor H. B. Gotaas and P. H. McGauhey considered problems of water supply in the West and the ability of reclaimed waters to help solve the problems. Many prominent Sanitary Engineers took part in the program which considered quality, quantity, economic, administrative and legal problems.

* * * * * * * *

Two identical 2-week courses will be held this summer at the Robert A.

Taft Sanitary Engineering Center at Cincinnati for training of sanitary engineer reserve officers from the Army, Navy, Air Force, and the Public Health Service. Sponsored jointly by the Department of Defense and the Department of Health, Education, and Welfare, these courses entitled "Advanced Training for Sanitary Engineer Reserve Officers," represent a pioneering effort in pooling of facilities by the four Services in developing improved periodic training opportunities for reserve officers normally on inactive status. The courses are scheduled for June 4-16 and June 16-30, with quotas for 7 Army, 7 Navy, 12 Air Force, and 12 PHS officers for each course drawn from throughout the country.

The courses, which are specially designed for reserve officers normally on inactive status, will provide instruction in emergency relief both in natural disaster and civil and military defense operations, and in the most recent technical and professional developments in sanitary engineering fields including radiological health and water and air pollution control.

Also participating in the course, as special lecturers will be Mr. Henry Herz, Office of Manpower Utilization, Assistant Secretary of Defense; Dr. John Whitney, Director, Health Office, Federal Civil Defense Administration; Col. Michael Blew, Chief, Sanitation Branch, Utilities Operation's Division, Repairs and Utilities, with Chief of Engineers, Department of the Army; Mr. Ernest Boyce, Professor of Sanitary Engineering, University of Michigan; and Mr. Harold Whittaker, Executive Secretary, Subcommittee on Personnel and Training, National Research Council.

* * * * * * * *

President Eisenhower has named a 19-man National Committee for the Development of Scientists and Engineers. Dr. Howard L. Bevis, President of Ohio State University, will be chairman, and Dr. Eric A. Walker, dean of the College of Engineering and Architecture at Pennsylvania State University, will be vice chairman of the committee. The other members represent various organizations in the fields of education, labor, science, and local government. The appointment of the special committee "to foster the development of more highly qualified technological manpower" followed a recommendation made by an inter-departmental government committee designated by the President to study the problem of increasing our supply of qualified scientists and engineers. The President directed all Government departments and agencies to cooperate fully with the new committee and "strengthen in every appropriate way their own activities which can contribute to the development and effective utilization of scientists and engineers."

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The Federation of Sewage and Industrial Wastes Association revised the William D. Hatfield Award Rules to recognize operators of sewage and waste treatment plants who are doing an outstanding job in performance of their duties. The award is based on better public relations between the plant operator and the public; businesslike accounting of expenditure of funds and care of the treatment plant and accessories entrusted to the operator; outstanding reports, and; advancement of the art and knowledge of sewage and waste treatment by dissemination of basic information and data concerning a particular plant and process through papers, articles, meetings and reports.

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Frank E. DeMartini, USPHS Regional Engineer in San Francisco was transferred May 15 to the Robert A. Taft Sanitary Engineering Center at Cincinnati. Frank's new duties will be to assist States with Air Pollution Control problems.

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The Ninth Florida Municipal and Sanitary Engineering Conference was held at the University of Florida April 17 and 18, 1956. The subject of this Conference was "Atmospheric Pollution."

* * * * * * * * * *

The Fifth Southern Municipal and Industrial Waste Conference was held at the University of North Carolina in Chapel Hill on April 5 & 6, 1956. These conferences have been organized jointly by North Carolina State College, Duke University and the University of North Carolina for the purpose of bringing together representatives of industry, municipalities and other governmental agencies responsible for developing policies relating to the preservation and utilization of our water resources in the southeastern part of the United States.

Following the keynote address by Prof. Gordon M. Fair of Harvard University on the theme, 'there were general sessions on quantity and quality requirements for drinking, bathing, fishing, agricultural and industrial waters.' On Friday afternoon, a general session was devoted to methods for establishing waste disposal requirements. Separate technical sessions were held on (1) Textile wastes; (2) Chemical industry wastes; (3) Food processing wastes; and (4) Municipal wastes.

* * * * * * * * * *

A meeting of the Executive Committee of the Sanitary Engineering Division was held in Kansas City, Mo., April 7. Roy Morton, Chairman, Dick Hazen and Art Caster were in Ray Lawrence's home city attending the ASCE Technical Division Procedures Conference and learned that Ralph Fuhrman was in the city on other business so it was decided to consider some of the Division's official business.

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Ralph Hone and Company has announced the moving of their offices to 147 San Vicente Blvd., Beverly Hills, California.

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The advantage of being bald is that when you expect callers, all you have to do is straighten your tie.

--Anon

* * * * * * * * * *

"It is much more important to be human than to be important."

--Will Rogers.

DO YOUR PUBLIC RELATIONS MEASURE UP?

Paul W. Reed

The good salesman has many attributes which contribute to his success, and good public relations is one of the most valuable. Since the sanitary engineer in the field of public health is basically a salesman of community health, it might be desirable to see how he measures up in this regard.

Much has been said and written about public relations but reduced to its simple elements, public relations are those things which one does to create a favorable impression. Public opinion is no particularly mysterious force. It is only the sum total of what people think about a certain person or subject. The public, or a segment of it, can think well of you, your job., etc., or have a poor opinion of these matters.

A public relations program need not be a complicated or formal program. Being a good citizen is good personal public relations. One of the essentials, of course, is that people know about you, your job, etc., if they are to have an opinion.

One of the greatest stumbling blocks to effective public relations is the false modesty which the sanitary engineer erects as a barrier between himself and the public. The sanitary engineer, particularly those in public health agencies, and the newspaper reporter are strangers. Let the newspaper reporter try to get a story and the engineer will freeze up and, if he consents to talk to the reporter at all, will snow him under with details and technical lingo. Is it any wonder that the article which appears (provided, of course, that the reporter doesn't throw up his hands in disgust) often contains errors? Why not assure accuracy by interpreting your story in simple interesting language instead of forcing the reporter to do the interpretation.

People thirst for knowledge. This thirst takes many forms for all people are not alike. Some pride themselves on knowing batting averages, some like history, some like science, and so on through a long list of interests. This basic reaction can be directed to the matters in which you are interested if you will take the time to present it in an interesting manner.

We all know that food tastes best when we are hungry and that we become sick if we eat too fast, or too much. This fact should be remembered in public relations programs—catch people when they are hungry, but don't feed them too fast or too much.

What do we mean? Let us use an illustration. You started and are continuing to read this article to satisfy a desire (or hunger) to better yourself. Perhaps it's technical, perhaps it's social—it really doesn't make much difference for you are still reading and it is hoped that you are in a receptive mood. Advantage is taken of that fact to try to sell an idea.

Secondly, this article is arranged so it follows a fairly logical sequence and is easy to read. It is not overburdened with statistical data so you are not being fed too fast.

And now as we approach the end of the article, another requirement is being fulfilled—you have not (I hope) been fed too much. All persons have a limit to their capacity which should not be exceeded.

Lastly, let us remember that it was Voltaire who said "The only way to compel men to speak good of us is to do good."

NEWS OF LOCAL SECTIONS

Harry P. Kramer, Chief of Training Section, at the Robert A. Taft Sanitary Engineering Center recently presented a talk before the Cincinnati A.S.C.E. section on recent developments in the field of stream pollution study. With the use of color slides, he very effectively described the roles played by bacteriologists, biologists, micologists, and other scientists in the field. He also told of several new laboratory methods which are being studied and developed as possible replacements for such traditional sewage strength determinations as BOD and the dilution method of bacterial analysis.

Of special interest to the group was the membrane type micro-filter for use in bacterial analyses. Mr. Kramer displayed several types of this apparatus for use in the laboratory and the field, and explained that bacterial counts can be obtained directly and not statistically as in the present standard analysis method.

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A. A. Thomas of Metcalf & Eddy talked to the New York City Metropolitan Section on the Middlesex County Sewer Authority on April 18th. The next Sanitary Engineering program for this section will be June 13 when a round table type of meeting will be held. The topic for the meeting will be "Design from an operator's point of view."

* * * * * * * * * *

Please cooperate by sending news items of interest to:

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[illegible]

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PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW) divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper numbers are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 861 is identified as 861 (SM1) which indicates that the paper is contained in issue 1 of the Journal of the Soil Mechanics and Foundations Division.

VOLUME 81 (1955)

JUNE: 702(HW), 703(HW), 704(HW)c, 705(IR), 706(IR), 707(IR), 708(IR), 709(HY)c, 710(CP), 711(CP), 712(CP), 713(CP)c, 714(HY), 715(HY), 716(HY), 717(HY), 718(SM)c, 719(HY)c, 720(AT), 721(AT), 722(SU), 723(WW), 724(WW), 725(WW), 726(WW)c, 727(WW), 728(IR), 729(IR), 730(SU)c, 731(SU).

JULY: 732(ST), 733(ST), 734(ST), 735(ST), 736(ST), 737(PO), 738(PO), 739(PO), 740(PO), 741(PO), 742(PO), 743(HY), 744(HY), 745(HY), 746(HY), 747(HY), 748(HY)c, 749(SA), 750(SA), 751(SA), 752(SA)c, 753(SM), 754(SM), 755(SM), 756(SM), 757(SM), 758(CO)c, 759(SM)c, 760(WW)c.

AUGUST: 761(BD), 762(ST), 763(ST), 764(ST), 765(ST)c, 766(CP), 767(CP), 768(CP), 769(CP), 770(CP), 771(EM), 772(EM), 773(SA), 774(EM), 775(EM), 776(EM)c, 777(AT), 778(AT), 779(SA), 780(SA), 781(SA), 782(SA)c, 783(HW), 784(HW), 785(CP), 786(ST).

SEPTEMBER: 787(PO), 788(IR), 789(HY), 790(HY), 791(HY), 792(HY), 793(HY), 794(HY)c, 795(EM), 796(EM), 797(EM), 798(EM), 799(EM)c, 800(WW), 801(WW), 802(WW), 803(WW), 804(WW), 805(WW), 806(HY), 807(PO)c, 808(IR)c.

OCTOBER: 809 (ST), 810 (HW)c, 811 (ST), 812 (ST)c, 813 (ST)c, 814(EM), 815(EM), 816(EM), 817(EM), 818(EM), 819(EM)c, 820(SA), 821(SA), 822(SA)c, 823(HW), 824(HW).

NOVEMBER: 825(ST), 826(HY), 827(ST), 828(ST), 829(ST), 830(ST), 831(ST)c, 832(CP), 833(CP), 834(CP), 835(CP)c, 836(HY), 837(HY), 838(HY), 839(HY), 840(HY), 841(HY)c.

DECEMBER: 842(SM), 843(SM)c, 844(SU), 845(SU)c, 846(SA), 847(SA), 848(SA)c, 849(ST)c, 850(ST), 851(ST), 852(ST), 853(ST), 854(CO), 855(CO), 856(CO)c, 857(SU), 858(BD), 859(BD), 860(BD).

VOLUME 82 (1956)

JANUARY: 861(SM1), 862(SM1), 863(EM1), 864(SM1), 865(SM1), 866(SM1), 867(SM1), 868(HW1) 869(ST1), 870(EM1), 871(HW1), 872(HW1), 873(HW1), 874(HW1), 875(HW1), 876(EM1)c, 877 (HW1)c, 878(ST1)c.

FEBRUARY: 879(CP1), 880(HY1), 881(HY1)c, 882(HY1), 883(HY1), 884(IR1), 885(SA1), 886(CP1), 887(SA1), 888(SA1), 889(SA1). 890(SA1), 891(SA1), 892(SA1), 893(CP1), 894(CP1), 895(PO1) 896(PO1), 897(PO1), 898(PO1), 899(PO1), 900(PO1), 901(PO1), 902(AT1)c, 903(IR1)c, 904 (PO1)c, 905(SA1)c.

MARCH: 906(WW1), 907(WW1), 908(WW1), 909(WW1), 910(WW1), 911(WW1), 912(WW1), 913 (WW1)c, 914(ST2), 915(ST2), 916(ST2), 917(ST2), 918(ST2), 919(ST2), 920(ST2), 921(SU1), 922(SU1), 923(SU1), 924(ST2)c.

APRIL: 925(WW2), 926(WW2), 927(WW2), 928(SA2), 929(SA2), 930(SA2), 931(SA2), 932(SA2)c, 933(SM2), 934(SM2), 935(WW2), 936(WW2), 937(WW2), 938(WW2), 939(WW2), 940(SM2), 941 (SM2), 942(SM2)c, 943(EM2), 944(EM2), 945(EM2), 946(EM2)c, 947(PO2), 948(PO2), 949(PO2), 950(PO2), 951(PO2), 952(PO2)c, 953(HY2), 954(HY2), 955(HY2)c, 956(HY2), 957(HY2), 958 (SA2), 959(PO2), 960(PO2).

MAY: 961(IR2), 962(IR2), 963(CP2), 964(CP2), 965(WW3), 966(WW3), 967(WW3), 968(WW3), 969 (WW3), 970(ST3), 971(ST3), 972(ST3)c, 973(ST3), 974(ST3), 975(WW3), 976(WW3), 977(IR2), 978(AT2), 979(AT2), 980(AT2), 981(IR2), 982(IR2)c, 983(HW2), 984(HW2), 985(HW2)c, 986(ST3), 987(AT2), 988(CP2), 989(AT2).

JUNE: 990(PO3), 991(PO3), 992(PO3), 993(PO3), 994(PO3), 995(PO3), 996(PO3), 997(PO3), 998 (SA3), 999(SA3), 1000(SA3), 1001(SA3), 1002(SA3), 1003(SA3)c, 1004(HY3), 1005(HY3), 1006 (HY3), 1007(HY3), 1008 (HY3), 1009 (HY3), 1010 (HY3)c, 1011 (PO3)c, 1012 (SA3), 1013 (SA3), 1014(SA3), 1015(HY3), 1016(SA3), 1017(PO3), 1018(PO3).

c. Discussion of several papers, grouped by Divisions.

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